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Office of Prevention,
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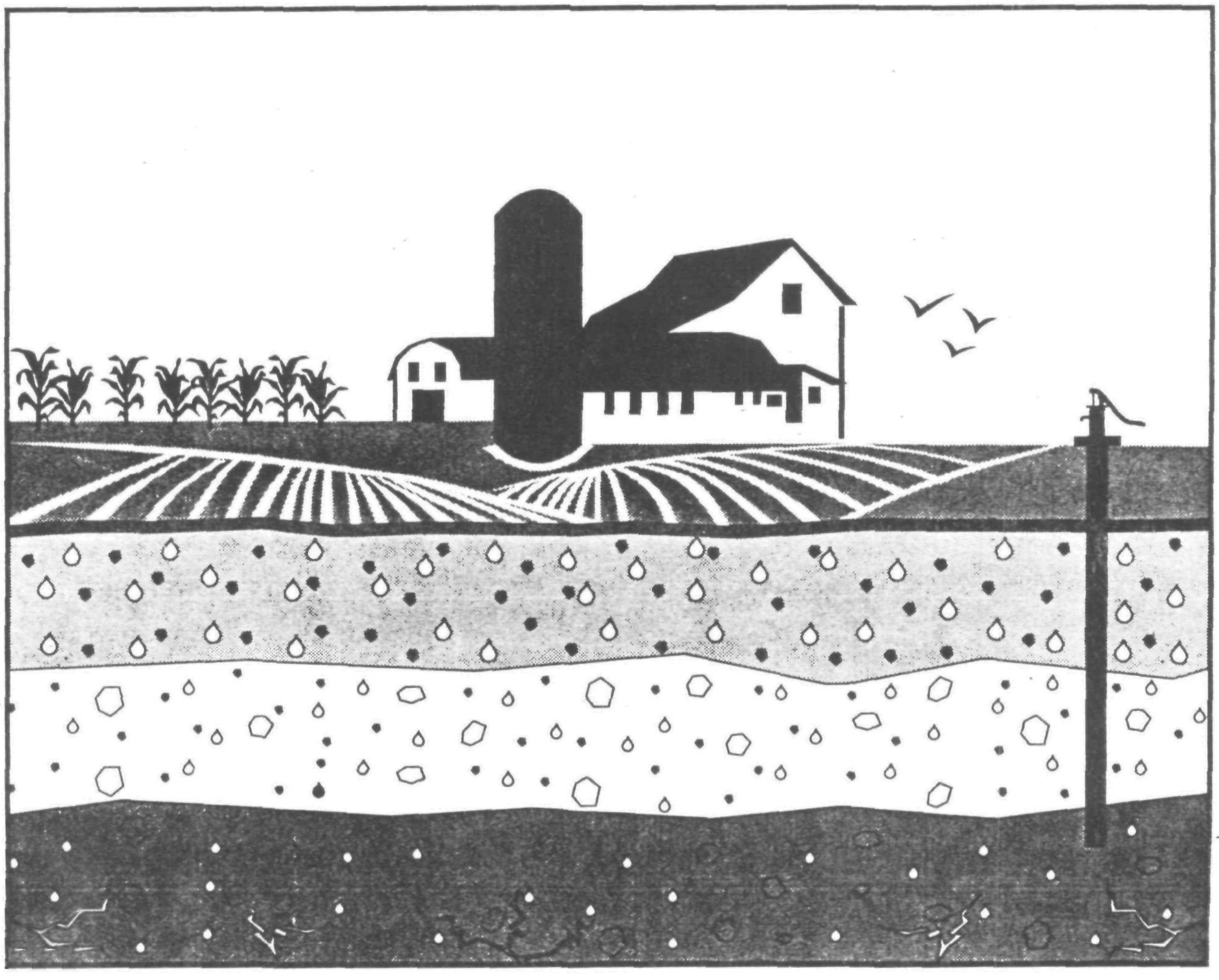
Assessment, Prevention, Monitoring, and Response Components of State Management Plans

Appendix B



Appendix to the Guidance for Pesticides and Ground Water State Management Plans

APPENDIX B:

ASSESSMENT, PREVENTION, MONITORING, AND RESPONSE COMPONENTS OF STATE MANAGEMENT PLANS

IMPLEMENTATION DOCUMENT FOR THE
PESTICIDES AND GROUND WATER STRATEGY

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF PESTICIDE PROGRAMS

Preface

Support for the preparation of this document was provided to EPA's Office of Pesticide Programs by SRA Technologies, Inc., Research Triangle Institute, and ICF Incorporated. The document is not intended to provide detailed technical information on "how to do" the activities that are components of a State Management Plan (SMP). Rather, this appendix (1) is a resource and reference document that describes where to go for information in developing components of an SMP; (2) briefly describes factors to consider and a range of options that States may use in developing approaches that are appropriate to their local conditions and needs; and (3) provides examples of approaches that have been used. This appendix provides references and points of contact wherever appropriate to direct the user to the most useful sources of information. The contents of this document do not necessarily reflect the joint or separate views and policies of any EPA program office or of the Agency.

Acknowledgements

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Chapter 1
Introduction

The general goal of EPA's Pesticides and Ground Water Strategy is to manage the use of pesticides in order to prevent unreasonable adverse effects to human health and the environment and to protect the environmental integrity of the nation's ground water resources. Prevention is the central principle of EPA's approach to managing pesticide use in order to protect ground water resources. Through the implementation of State Management Plans (SMPs) for pesticides, States may promote the environmentally sound use of pesticides that might otherwise pose an unreasonable risk to ground water resources. Although EPA can require SMPs only through a chemical-specific regulatory action, States are strongly encouraged to take the initiative voluntarily to develop Generic SMPs that establish the framework for SMPs that address specific pesticides (Pesticide SMPs) even before EPA requires SMPs through a chemical-specific regulatory action. The Guidance for Pesticides and Ground Water State Management Plans, with its Appendices, establishes the components of SMPs and provides approaches and methods to assist States in developing and implementing SMPs.

1.1 Purpose and Scope

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) provides EPA with the regulatory authority to require States to develop SMPs to continue to use a pesticide that would otherwise pose an unreasonable risk and be unavailable due to cancellation or lack of registration. Through a chemical-specific regulatory action under FIFRA Section 3 or 6, an SMP (referred to as a Pesticide SMP) becomes a required condition for the sale and use of a pesticide. Because States may be required to develop more than one Pesticide SMP, States may find it beneficial to develop a Generic SMP that contains components common to most Pesticide SMPs. EPA encourages States to develop Generic SMPs, but they are not required. If a State decides to develop a Generic SMP and seek EPA concurrence, the Generic SMP must address all 12 SMP components in the detail necessary to obtain EPA concurrence.

EPA has identified the following 12 components that must be addressed in both Generic and Pesticide SMPs:

1. State's philosophy and goals toward protecting ground water;
2. Roles and responsibilities of State agencies;
3. Legal authority;
4. Resources;
5. Basis for assessment and planning;
6. Monitoring;
7. Prevention actions;

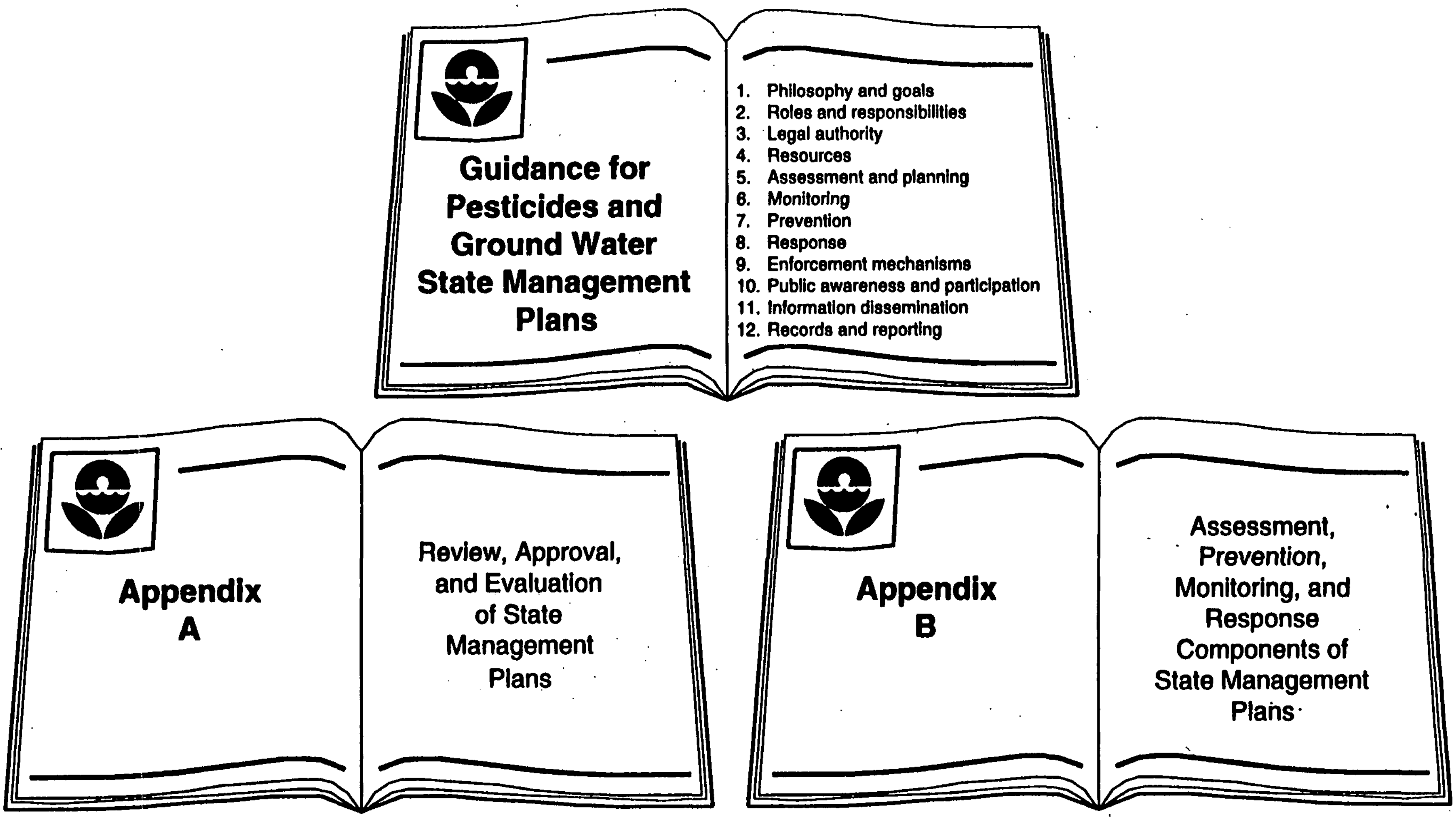
8. Response to detections of pesticides;
9. Enforcement mechanisms;
10. Public awareness and participation;
11. Information dissemination; and
12. Records and reporting.

The extent to which each of these necessary components of a Generic or Pesticide SMP is addressed will depend on the State's ground water protection philosophy, ground water vulnerability, degree of pesticide use, agronomic practices, and the use and value of its ground water. The type and level of information included in the SMP must be sufficient to result in the adequate implementation of the SMP, given the unique characteristics of the State. The individual States are the best sources of information regarding the circumstances surrounding development and implementation of this program. The Guidance for Pesticides and Ground Water State Management Plans and a support document, Appendix A: Review, Approval, and Evaluation of State Management Plans, provide guidance on the type and level of information that may be necessary to address each of the 12 components adequately.

This support document, Appendix B: Assessment, Prevention, Monitoring, and Response Components of State Management Plans, is a guide to technical information that will assist States in the development of the assessment, monitoring, prevention, and response components of SMPs. The development of plans to determine and monitor the quality of the ground water resources, to prevent unreasonable adverse effects to human health and the environment, to protect the environmental integrity of the nation's ground water resources, and to respond to detections of pesticides in ground water are technically complex projects. This support document presents a range of approaches that may help guide States in the development of SMPs. This appendix provides an overview of the technical considerations that should be addressed in the development of SMPs; it does not attempt to provide a complete discussion of complex technical matters. Furthermore, this appendix cannot be exhaustive; prevention, monitoring, and response strategies other than those specifically described also may be appropriate and acceptable in SMPs. Finally, States also need to recognize the importance of involving local entities (e.g., local extension offices, local planning offices, etc.), as well as all applicable State agencies, in selecting and implementing the appropriate tools or mechanisms for protecting ground water resources from pesticide contamination.

Appendix B represents EPA guidance to States on developing Generic and Pesticide SMPs. The language contained in this document on the 12 components of a Pesticide SMP will also be proposed for public comment in an upcoming regulation specifying pesticides for which a Pesticide SMP will be required. This guidance document does not establish a binding norm -- Agency decisions to approve or disapprove Pesticide SMPs will be made on a case-by-case basis by applying the regulation to the specific facts of the case.

Figure 1
Sources of Guidance on SMPs



1.2 Roadmap of Appendix B

This appendix is organized as follows:

- Chapter 2 gives an introduction to philosophies of ground water protection and response and a summary of EPA's current ground water protection programs.

- Chapter 3 gives a description of technical tools and sources of technical information for assessment and planning. It includes aquifer sensitivity and vulnerability assessment methods, techniques and sources to assess pesticide use, and spatial data base methodologies.

- Chapter 4 provides support for the development of the prevention component of a Generic or Pesticide SMP.

- Chapter 5 provides support for the development of the monitoring component of a Generic or Pesticide SMP.

- Chapter 6 provides support for the development of the response component of a Generic or Pesticide SMP.

- Chapter 7 is a guide to sources of technical information.

1.3 References

U.S. EPA. Office of Pesticides and Toxic Substances, Office of Pesticide Programs, October 1990. Pesticides and Ground Water Strategy. EPA 21T-1022.

U.S. EPA. Office of the Administrator, July 1991. Protecting The Nation's Ground Water: EPA's Strategy for the 1990s. EPA 21Z-1020.

Chapter 2

Development of Ground Water Protection, Prevention, and Response Philosophy

The goal of EPA's Pesticides and Ground Water Strategy is to prevent contamination of ground water resources that presents an unreasonable risk of adverse effects to human health and the environment resulting from the normal, registered use of pesticides, by taking appropriate actions in vulnerable areas. In determining appropriate prevention and protection strategies, EPA will also consider the use, value, and vulnerability of ground water resources. Because pesticides have extensive beneficial uses, EPA is seeking through SMPs to promote the environmentally sound use of pesticides that might otherwise not be available due to chemical-specific regulatory actions.

States should consider EPA's goal in formulating approaches to protect ground water resources and manage pesticides that present health or environmental risks. While States are not constrained to follow EPA's philosophy, goals, and priorities as set forth in the Pesticides and Ground Water Strategy, State programs must be at least as protective. SMPs will vary based on the extent of the State's unique hydrogeologic and institutional characteristics, including its ground water protection philosophy, the sensitivity of its ground water, degree of pesticide use, agronomic practices, and use and value of ground water. Therefore, a critical component of an SMP is the statement of a State's philosophy concerning ground water protection and its philosophy of response to ground water contamination resulting from normal uses of pesticides. Successful implementation of prevention, monitoring, and response plans ultimately depend on the establishment of clear ground water protection and response goals.

The Guidance for Pesticides and Ground Water State Management Plans specifies that both a Generic and a Pesticide State Management Plan should include:

- A statement that addresses which ground waters will be protected and the degree of protection which will be achieved under the SMP.

- The stated goal of protection efforts. The goal can use EPA established reference points, a more stringent standard than EPA established reference points, or maintain and protect ground water at pristine quality.

The balance of this chapter discusses topics involved in the ground water protection and response philosophy.

2.1 Ground Water Protection Philosophy

The State's ground water protection philosophy defines the waters to be considered in assessment, prevention, monitoring, and response plans. This philosophy is consistent with the philosophy contained in the States' Comprehensive State Ground Water Protection Program philosophy and addresses both the ground waters to be protected and the degree of protection to be achieved under the SMP. In accordance with EPA's Ground Water Strategy, ground water protection approaches should, at a minimum, be directed toward:

- Currently used and reasonably expected sources of drinking water; and

- Ground water that is closely hydrologically connected to surface waters affecting the integrity of associated ecosystems.

A State may set additional priorities for ground water protection based on its actual or potential vulnerability. The determination of ground water use, value, and vulnerability involves combining information on site-specific hydrogeologic conditions with information on ground water use and land-use practices that might influence ground water quality. Determinations of use and value require additional information such as the water quality, yield, accessibility, connection to important ecosystems, and existence of other more readily available or higher quality supplies.

> An example of a use-based priority system to address the protection of ground water is the system proposed by the **Texas Ground Water Protection Committee.** In this system, first priority is given to aquifers that supply current or future sources of drinking water. Moderately saline ground water supplies are given second priority in the Texas protection hierarchy because of their potential for future use and the possibility that they are connected hydraulically with first-priority waters. (Texas Ground Water Protection Committee. Draft Generic State Management Plan for Agricultural Chemicals in Ground Water. June, 1991.)

States may implement such differential protection philosophies through case-by-case assessments or, for example, through a ground water classification system. Most States have already established some form of ground water classification system. The <u>Pesticides and Ground Water Strategy</u> presumes that a major focus of ground water protection efforts will be on current and reasonably expected sources of drinking water and that States are in an appropriate position to judge the future uses of their ground water resources.

Recognizing the local variability of ground water resources and the complexity of predicting ground water contamination, ground water protection may be approached through a number of methods, including:

- Pollution prevention programs;
- Source control programs;
- Siting controls;
- Wellhead protection programs;
- Protection of future public water-supply areas; and
- Protection of aquifer recharge areas.

A number of EPA programs are designed to protect ground water resources. Some of these programs may provide grants to assist States in developing their own activities. Table 2-1 highlights the EPA programs that may be pertinent to SMP development. Measures that protect ground water from contamination by pesticides are discussed in Chapter 5.

2.2 Prevention and Response Philosophy

In the context of this document, the term "response" includes actions initiated after a pesticide is detected in ground water, as well as actions taken when the concentration of a pesticide reaches or exceeds a reference level (Chapter 6). As stated in the Pesticides and Ground Water Strategy, the point of failure for adverse health effects will be the maximum contaminant level (MCL) or long term health advisory set for the pesticide. The point of failure for prevention of adverse ecological effects will be the Water Quality Standards under the Clean Water Act.

A State's ground water protection goal affects the degree of response necessary following the detection of pesticides in ground water. Examples of States' ground water protection goals are illustrated below.

- **Minnesota's** ground water protection goal stresses preventing degradation. State law requires the maintenance of ground water in its natural state, implementation of preventive measures wherever practicable, and the development of new technologies and methods where current preventive measures are inadequate. Minnesota Statute 103H.001.

- **Michigan** has a nondegradation goal for all usable aquifers. A nondegradation standard is established for all aquifers that provide water for individual, public, industrial, or agricultural supplies. Part 22, Rules of the Michigan Water Resources Commission Act (1929).

- **Wisconsin** sets enforcement standards and preventive action limits for a number of potential ground water pollutants. Regulatory actions are instituted if the ground water concentration of a pesticide attains or exceeds an established standard or limit, as detected from a community, private, or monitoring well (Wisconsin Statutes, Chapter 161).

Table 2-1. Summary of Existing Ground Water Protection Programs

Program Title	Regulatory Authority	Description	Components
Comprehensive State Ground Water Protection Program	Through no direct statutory authority, the program derives authority to protect ground water from CWA §106 and §319, SDWA §1424(e) and §1428, CERCLA, RCRA, and FIFRA	Focuses on efficient and effective ground water protection through cooperative, consistent, and coordinated operation of all relevant federal, State, and local programs within a State	• Consists of a set of six strategic activities: (1) establish goal; (2) establish priorities, based on characterization of the resource, identification of sources of contamination, and programmatic needs; (3) define roles, authorities, responsibilities, resources, and coordinating mechanisms; (4) implement necessary activities; (5) information collection and management; and (6) public participation
Wellhead Protection Program	Safe Drinking Water Act Amendments of 1986, §1428	Focuses on protecting ground water used for public water supply	• Delineation of wellhead protection areas • Identification of contamination sources • Management approaches to differentially manage drinking water supplies
Nonpoint Source (NPS) Programs	Clean Water Act, §319	Requires States to describe the nature, extent, and causes of NPS pollution and report State programs to control this pollution; also requires States to identify best management practices and plans for their implementation	• NPS Assessment Report • NPS Management Program
Sole Source Aquifer Program	Safe Drinking Water Act of 1986, §1427	Allows EPA to designate an aquifer as a sole or principle source of drinking water	• Aquifer delineation and use evaluation • Management approaches to protect vulnerable aquifers • Designated aquifers require EPA review of federally funded projects to assure protection

Table 2-1. Summary of Existing Ground Water Protection Programs (continued)

Program Title	Regulatory Authority	Description	Components
Public Water System Supervision	Safe Drinking Water Act	State supervision of public water systems to prevent human exposure to waterborne contaminants	• Ground water monitoring and treatment • Monitoring waivers contingent upon vulnerability assessment • Implementation of well and ground water protection measures
UIC Program: Class V Wells (Agricultural drainage wells and irrigation return flow wells)	SDWA, §1421-1426	Program to protect underground sources of drinking water	• Development of agricultural best management practices to ensure agricultural drainage wells do not affect drinking water sources
Coastal Nonpoint Source Program	Coastal Zone Reauthorization Amendments of 1990, §6217	Development of State programs to ensure implementation of non-point source management measures	• Pesticide management activities
Chesapeake Bay Program	CWA, §117	Development and implementation of programs to restore and enhance Chesapeake Bay	• Development of agricultural BMPs

The Pesticides and Ground Water Strategy states that prevention of contamination and protection of the ground water resource is the central principle of EPA's approach to managing pesticide use. Specifically, the Strategy emphasizes the prevention of contamination of ground water resources that presents an unreasonable risk of adverse effects to human health and the environment resulting from the normal, registered use of pesticides, by taking appropriate actions in vulnerable areas. The State's response philosophy will provide direction to State agencies in determining what actions will be needed when 1) a pesticide is found, 2) pesticide concentrations increase over time, or 3) pesticide concentrations approach the reference point. This philosophy will also provide direction to State agencies in determining what actions will be needed if pesticide contamination reaches or exceeds the reference point.

EPA recommends that a State develop and implement a response philosophy that reflects its ground water protection philosophy, its aquifer sensitivity, and its history of pesticide use. Action levels which trigger responses should be percentages of the MCL, consistent with the level of ground water protection chosen by the State through its ground water protection philosophy. The development of the response component of SMPs and response actions are discussed in Chapter 6.

Chapter 3

Technical Tools for Assessment and Planning

The first technical component of both a Generic and a Pesticide SMP established by the Guidance for Pesticides and Ground Water State Management Plans is that the State establish its basis for assessment and planning. This requires that a State have adequate knowledge of its unique hydrogeologic settings, pesticide usage patterns, and agronomic practices. EPA, as part of its technical assistance program, will supply pesticide-specific information such as persistence and mobility data, detection limits, analytical methodology, and monitoring information. This information can assist States in developing the assessment and planning portions of an SMP.

A number of technical tools and technical information sources exist on aquifer sensitivity/ground water vulnerability, pesticide usage, and cropping patterns. In addition, different tools for organizing information, may be helpful to States in setting priorities for monitoring, prevention, and response efforts. States should use the tools discussed in this chapter to facilitate the development and implementation of management plans in accordance with the guidelines presented in Appendix A. Tools such as aquifer sensitivity assessments, pesticide use evaluations, and spatial data bases can be used in SMPs in a broad range of alternative combinations. Figure 3-1 illustrates these combinations, though it does not represent the full spectrum of alternatives. In addition, a State may choose to combine the elements in any number of ways, mixing, for example, selective assessment of ground water vulnerability with detailed pesticide usage information and a hybrid form of representation of the data. States should note that the methods presented in this chapter may not be applicable to all situations across States due to the unique circumstances that occur in each State. These tools and other sources of technical information are described in the following sections.

Figure 3-1. Range of Methods for Assessing Aquifer Sensitivity and Ground Water Vulnerability

	Aquifer Sensitivity	Ground Water Vulnerability	Representing Assessments of Aquifer Sensitivity and Ground Water Vulnerability
↑ Pesticide SMPs ↑	• Full assessment of State aquifer sensitivity at sub-county level • Apply aquifer sensitivity simulation method to test management options • Apply hybrid assessment method to determine leachability of specific pesticide(s)	• Full description of State pesticide use and cropping practices at sub-county level • Description of geographic use, application rates, application timing, application method for particular pesticide	• Full GIS mapping of State at sub-county level • Mixed GIS and topographic maps (i.e., GIS mapping of priority areas at sub-county level) • Computer data base (e.g., indexed by latitude and longitude)
Increasing Detail and Precision | Generic SMPs	• Assessment of ground water vulnerability for areas of high ground water use and value • Apply aquifer sensitivity screening method at the State level • Use reports of prior applications of assessment methods • Use reports of ground water classification based on hydrogeologic factors	• Acquisition of accurate pesticide use data for entire State that is updated periodically • Acquisition of pesticide use data for limited areas of State that is updated infrequently • Use of current State records and non-State sources • Use of reports of prior assessments of usage	• Topographic maps documented with transparent overlays • Topographic maps documented with field notes • Field notes

3.1 Aquifer Sensitivity and Ground Water Vulnerability Assessment Methods

The Guidance for Pesticides Ground Water State Management Plans states that the extent to which each of the 12 components of an SMP is addressed will depend on, among other factors, the State's aquifer sensitivity and ground water vulnerability efforts. States need to consider the sensitivity and vulnerability of their ground water resources to pesticides in order to develop appropriate preventive actions. A State may also establish priorities based on the magnitude of risks and the costs of prevention or remediation actions, provided these priorities are consistent with the overall goal of the SMP. Both a Generic and a Pesticide SMP should:

- Discuss the State's approach and activities to assess vulnerability (considering factors such as pesticide usage, soil type, depth to ground water, aquifer material, precipitation, and irrigation use) on a sub-county level[1] for the geographic area in which the State intends to allow pesticide use.

  In addition, the use of monitoring (see Component 6), modeling, other geographic planning methods or tools, such as Geographic Information Systems (GIS), or work developed by other programs used in developing the approach should be described. Sources of the above data must be identified. Assessment and planning efforts should utilize and integrate the data available from ongoing State and federal assessment and mapping programs such as those available from the USGS and USDA's Soil Conservation Service.

- Discuss how the State will determine current or reasonably expected sources of drinking water (taking into account factors such as land use, remoteness, quality and/or availability of alternative water supplies) and ground water that is hydrologically connected to surface water. If a State is affording priority protection to all ground water no matter the use and value, as many States are, then the State may not have to delineate and define these.

- Discuss how the State's assessment of ground water vulnerability and monitoring, and the use and value of ground water, will be used

[1] Both the General Accounting Office (GAO), in its report, Groundwater Protection, Measurement of Relative Vulnerability to Pesticide Contamination, and EPA, in the National Pesticide Survey Phase II Report, have reported that assessing vulnerability on the county level generally is not useful in predicting the vulnerability at smaller scales. Therefore, vulnerability assessments developed for State Management Plans should consider including sub-county level data, rather than county level data, based on factors discussed in Section 3.1.2.

to set priorities for protection activities, design and implement prevention and response programs, and determine and evaluate the effectiveness of management measures.

For example, the SMP may discuss how a combination of modeling and monitoring will be used to determine what management practices should be employed in those areas. Some States may choose to use information developed by one agency on pesticide use and cropping practices in combination with hydrogeologic sensitivity maps produced by another agency to determine specific ground water protection management measures to be implemented in vulnerable areas. A State also may decide to place a moratorium on pesticide use within Wellhead Protection Areas, critical recharge areas, or highly valued aquifers.

- Identify the limitations of the assessment and discuss how those limitations are taken into account in the design of prevention and response programs. For example, if a State applies prevention measures on broad regional or county-level designations, then sub-county level assessments may not be needed, but the State should explain why the measures chosen are likely to be adequate to meet program goals. Conversely, if a State plan allows sub-county or farm-level distinctions in applying prevention measures in order to avoid overregulation, it should explain the basis for making such distinctions, and how protection goals will be met.

Note: The State's assessment and priority should reflect the SMP goal (Component 1) and should be at a level that complements monitoring (Component 6), prevention (Component 7), and response (Component 8) activities. Over time, new or changed information from monitoring and on-going assessment activities should be used to refine and update the assessment.

In addition to the Generic Plan Criteria listed above, a Pesticide Plan must:

- Describe the State's available pesticide use data (e.g., geographic use, application rates) and how it will be factored into assessing vulnerability.

Aquifer sensitivity is the relative ease with which a contaminant (in this case a pesticide) applied on or near a land surface can migrate to the aquifer of interest. Aquifer sensitivity is a function of the intrinsic characteristics of the geologic materials in question, any overlying saturated materials, and the overlying unsaturated zone. Sensitivity is not dependent on agronomic practices or pesticide characteristics. ***Ground water vulnerability*** is the relative ease with which a contaminant (in this case a pesticide) applied on or near a land surface can migrate to the aquifer of interest under a given set of agronomic management practices, pesticide characteristics, and aquifer sensitivity conditions.

Section 3.1.1 summarily reviews readily accessible sensitivity and vulnerability assessment methods. Section 3.1.1 identifies and discusses method categories and the methods that comprise those categories; Section 3.1.2 identifies factors to consider in selecting methods; and Section 3.1.3 discusses the documentation and evaluation of assessment methods. The reader should note that Section 3.1 does not provide extensive information on how to use the methods.

3.1.1 Method Categories

A number of methods have been developed in the last decade that assess aquifer sensitivity and ground water vulnerability to pesticide contamination. Research is ongoing to perfect some of these methods and to determine which ones perform most accurately in different situations to predict pesticide contamination. Federal agencies and other organizations are currently reviewing many of these methods (Section 3.1.3). The Ground Water Protection Division of EPA's Office of Ground Water and Drinking Water grouped the methods into the following two categories:

(1) Aquifer sensitivity methods; and
(2) Ground water vulnerability methods.

Pesticide leaching methods, a subcategory of ground water vulnerability methods, require pesticide-specific and soil-specific information, and thus incorporate intrinsic hydrogeological data and pesticide characteristics. Various statistical tools supplement sensitivity and vulnerability methods and serve to analyze relationships of one or more hydrogeologic factors to known occurrences of pesticides in ground water. Selected statistical tools are provided in Table 3-1. The information used to summarize these methods was largely derived from the EPA Technical Assistance Document (TAD) A Review of Methods for Assessing Aquifer Sensitivity and Ground Water Vulnerability to Pesticide Contamination developed by the Office of Ground Water and Drinking Water (September 1993).

Aquifer Sensitivity Methods

The methods under this category consider only hydrogeologic factors and they do not consider pesticides or management factors.

Aquifer sensitivity methods use hydrogeologic characteristics to determine an aquifer's intrinsic susceptibility to pesticide contamination. These methods involve either the comparison of areas of known pesticide contamination to criteria judged to represent conditions that are sensitive to contamination, or the calculation of a rating or numerical score for each area. Methods that generate scores are designed to provide a relative measure of the sensitivity of one area compared to other areas. The Leachability Classes of Kansas Soils method is one example of a comparison method. Examples of scoring

Table 3-1. Description of Statistical Tools (adapted from EPA, 1993)

Name of Method Author(s) and date:	Contact Address	Method Description
Multiple Regression Statistical Analyses J. Steichen, J. Koeliker, D. Grosh, A. Heiman, R. Yearout (1988)	Agricultural Engineering Department Kansas State University Manhattan, Kansas 66502	The method consists of a multiple regression model used to relate pesticide concentrations in ground water to the age of a well, land use in the vicinity of the well, and the distance to the closest possible source of pesticide contamination.
Multiple Regression Statistical Analyses H. Chen, D. Druliner (1987)	U.S. Geological Survey 406 Federal Building 100 Centennial Mall North Lincoln, Nebraska 68508	This multiple regression method was used to describe results of existing ground water contamination and the factors affecting that contamination within six study areas in Nebraska. The researchers focused on nine independent variables including: hydraulic gradient; hydraulic conductivity; specific discharge; depth to water; well depth; annual precipitation; soil permeability; irrigation-well density; and annual nitrogen fertilizer use.
Discriminant Statistical Analysis/Soil Taxonomy and Surveys R.R. Teso, T. Younglove, M.R. Peterson, D.L. Sheeks, R.E. Gallavan (1988)	Environmental Hazards Assessment Program University of California Riverside, California 92521	This method uses a multivariate statistical approach (Fisher's Linear Discriminant analysis) with soil taxon units to delineate sensitive areas. The method utilizes soil survey reports, the U.S. rectangular coordinate system, and available data from ground water and pesticide analyses.

methods include Agricultural DRASTIC, Wisconsin's Ground Water Susceptibility Project, and SEEPAGE. Table 3-2 briefly describes a number of aquifer sensitivity methods.

Ground Water Vulnerability Methods

Ground water vulnerability methods include pesticide leaching methods (discussed earlier), pesticide use/aquifer sensitivity methods, and computer simulation models. Pesticide use/aquifer sensitivity methods involve combining pesticide use information and the results of an aquifer sensitivity method. Computer simulation models involve the fate and transport of pesticides in the soil and/or aquifer systems and contain mathematical equations that describe the processes or phenomena related to pesticide transport. Examples of simulation models are described in Table 3-3. For a more detailed discussion, see EPA's Technical Assistance Document (TAD), A Review of Methods for Assessing Aquifer Sensitivity and Ground Water Vulnerability to Pesticide Contamination (U.S. EPA, 1993).

Wisconsin's Ground Water Susceptibility Project. The Wisconsin Department of Natural Resources (in cooperation with the U.S. Geological Survey [USGS], the Wisconsin Geological and Natural History Survey, and the University of Wisconsin) evaluated hydrogeological factors that influence the contamination sensitivity of Wisconsin's ground water. Five factors were identified as important in determining the ease with which a contaminant can be transported through overlying materials into the ground water. These factors are 1) depth to bedrock, 2) type of bedrock, 3) soil characteristics, 4) depth to water table, and 5) characteristics of the surficial deposits. A composite ground water contamination susceptibility map was prepared for the State (1:1,000,000). The map is a composite of hydrogeologic data only and does not incorporate individual characteristics of a specific contaminant or the subsurface release of a contaminant. State agencies use the composite map to decide where further study on ground water impacts is needed, and to make sound ground water management and land use decisions. The map is limited, as it is compiled from very generalized Statewide information at a small scale (i.e., the map cannot be used for siting disposal facilities or locating an industry).

Kansas' Use of an Aquifer Sensitivity Method. Kansas devised a classification system to account for protection offered from soils that overlie the aquifers in Kansas. This classification system relied on an aquifer sensitivity method to group Kansas soils into four classes of susceptibility based on soil texture and water infiltration rate (permeability). Coarse-textured soils were generally considered to be more susceptible to pesticide leaching than fine-grained soils. Emphasis was placed on the limiting soil (e.g., highest clay content or lowest permeability) in the horizon. A leaching susceptibility map of Kansas soils was prepared based on the general soils map available from the National Cooperative Soil Survey.

Table 3-2. Description of Aquifer Sensitivity Methods (adapted from EPA, 1993)

Name of Method Author(s) and date:	Contact Address	Method Description
Agricultural DRASTIC L. Aller, T. Bennett, J.H. Lehr, R.J. Petty (1985)	U.S. EPA, Robert S. Kerr, Environmental Research Laboratory, Ada, Oklahoma 74820	DRASTIC is an acronym for a ranking system that evaluates seven hydrologic factors. Each factor is independently weighted and then added together to form a numerical index. This index represents the areas' relative degree of pollution potential by pesticides compared to other areas.
AQUIPRO R.N. Passero, F.J. Cohen, S.J. Dulaney, P.M. Half, H. Moaddel (1988)	Center for Water Research, Department of Geology, Western Michigan University, Kalamazoo, Michigan 49008	AQUIPRO was developed as an alternative aquifer vulnerability ranking system for use in Southwest Michigan where glacial drift aquifers exist. Unlike DRASTIC, AQUIPRO is based on the assumption that clays and clayey glacial sediment provide natural protection for glacial aquifers. This method uses a relative ranking system. It accounts for the weighted depth of the well and the weighted average thickness of the protective clay and clayey glacial sediments and confining and semi-confining bedrock types. The method has been used to indicate aquifer vulnerability/protective scores for individual wells and is currently being revised.
Greater Denver Ground Water Sensitivity Assessment G. Hearne, M. Wireman, A. Campbell, S. Turner, G. Ingersoll (1992)	United States Geological Survey, Water Resources Division, Federal Center, Denver, Colorado 80225	Geology, depth to water, soils, and elevation data were processed to produce maps of seven hydrogeologic factors. Spatial and attribute data for these maps were stored and processed using GIS software to produce a map depicting sensitivity of the uppermost aquifer. Each sensitivity map unit is described in quantitative terms.
Idaho's Ground Water Vulnerability Project Idaho Department of Health and Welfare (1991)	Idaho Department of Health and Welfare, Division of Environmental Quality, 1410 N. Hilton, Statehouse Mall, Boise, Idaho 83720-9000	This method uses a modified Agricultural DRASTIC scoring system. Modifications include: 1) a large amount of data on well depths; 2) more detailed soil data; 3) incorporation of irrigation as the largest contributor to ground water recharge; 4) deletion of topography as a factor; and 5) subdivision of the soil characteristics factor into four sub-factors.

Table 3-2. Description of Aquifer Sensitivity Methods (continued) (adapted from EPA, 1993)

Name of Method Author(s) and date:	Contact Address	Method Description
Leachability Classes of Kansas Soils D.E. Kissel, O.W. Bidwell, J.F. Kientz (1982)	Kansas State University, Kansas Agricultural Experiment Station, Manhattan, Kansas 66502	This method groups Kansas soils into four classes of susceptibility. Susceptibility is based on the soil profile texture and water infiltration rate.
Minnesota's Geologic Sensitivity Methods Geologic Sensitivity Workgroup, Minnesota Department of Natural Resources (1991)	Geologic Sensitivity Workgroup, Minnesota Department of Natural Resources	The Minnesota method applies geologic sensitivity criteria using one to three levels of assessment. The geologic sensitivity criteria are five overlapping ranges of known or estimated vertical travel times that have been assigned relative sensitivity ratings from very high to very low. A Level 1 assessment estimates the sensitivity of the water table aquifer using surface and near-surface information. A Level 2 assessment estimates the sensitivity of the water table aquifer using information from the entire vadose zone. A Level 3 assessment evaluates the sensitivity of deep, confined aquifers.
Potential for Contamination of Shallow Aquifers in Illinois R.C. Berg, J.P. Kempton, Keros Cartwright (1984)	Illinois Department of Energy and Natural Resources, State Geological Survey Division, Champaign, Illinois 61820	This method consists of two maps representing the potential for contamination of shallow aquifers by 1) land burial of wastes and 2) surface and near-surface waste disposal. Geologic materials to depths of 20 and 50 feet were differentiated by thickness, texture, permeability, and stratigraphic position to construct geologic stack-unit maps. The maps (1: 500,000) show the distribution of geologic material sequences and their comparative ratings. Each sequence is rated for the susceptibility of its aquifers to contamination from waste disposal practices. The land burial map of municipal wastes shows 18 sets of geologic sequences, whereas the surface and near-surface waste disposal map shows 13 sets of geologic sequences. Potential disposal sites should be investigated in the field on a site-specific basis.

Table 3-2. Description of Aquifer Sensitivity Methods (continued) (adapted from EPA, 1993)

Name of Method Author(s) and date:	Contact Address	Method Description
SEEPAGE J.S. Moore (1988)	U.S. Department of Agriculture, Soil Conservation Service, Northeast National Technical Center Chester, Pennsylvania	This method uses a relative ranking system for seven soil/aquifer parameters. Site Index Numbers (SINs) are calculated for different areas and compared to determine the degree of aquifer sensitivity. The method accounts for whether the potential source of the contaminant is concentrated or dispersed.
South Dakota Aquifer Contamination Vulnerability Maps G. Lemme, C.G. Carlson, B.R. Khakural, L. Knutson, L. Zaveskey (1989)	Plant Science Department, South Dakota State University and U.S. Department of Agriculture, Soil Conservation Service Brookings, SD 57007-001	This method integrates soil, topographic and geologic data to develop sensitivity values for surface water and aquifer contamination. Drilling logs and soil survey maps are used to assess aquifer sensitivity. Sensitivity is based on the permeability of the overlying material (percent surface organic matter and thickness). The results are grouped into four classes and represented on maps.
Wisconsin Soil Attenuation Potential K.J. Cates, F.W. Madison (1990)	Nutrient and Pest Management, University of Wisconsin-Extension, Madison, Wisconsin 53706	This method evaluates soil attenuation potentials within selected Wisconsin counties. Attenuation potentials are presented on county maps at a scale of 1:100,000. Method includes subsurface geological materials and depth to ground water for the Farmstead Assessment System.
Wisconsin's Ground Water Susceptibility Project Wisconsin Department of Natural Resources (WDNR), Wisconsin Geological and Natural History Survey (1987)	WDNR Bureau of Water Resources Management P.O. Box 7921 Madison, Wisconsin 53707	Five hydrogeologic factors are identified as important parameters in determining contaminant transport from overlying materials to the ground water. Each of the five factors are digitized on a computer and overlaid to produce a composite map.

Table 3-3. Description of Ground Water Vulnerability Methods (adapted from EPA, 1993)

Name of Method Author(s) and date:	Contact Address	Method Description
Agricultural Pesticides and Ground Water in North Carolina: Identification of the Most Vulnerable Areas D.H. Moreau, L.E. Danielson (1990)	Water Resources Research Institute North Carolina State University P.O. Box 7912 Raleigh, NC 27696-7912	This aquifer sensitivity method combines DRASTIC with pesticide use/loading data. Relative vulnerability is categorized as: 1) most vulnerable; 2) next most vulnerable; 3) next least vulnerable; and 4) least vulnerable.
CHEMRANK D.L. Nofziger, P.S.C. Rao, A.G. Hornsby (1988)	Florida Cooperative Extension Service University of Florida Gainesville, Florida 32611	CHEMRANK is an interactive microcomputer model. It uses four schemes to screen a group of organic chemicals for their likelihood to reach ground water. Two of the schemes are based on the rates at which these chemicals might leach through the unsaturated zone. The other two schemes use relative chemical mobility and degradation rates as the basis for the ranking. The two simple ranking indices/schemes assume that steady water-flow conditions prevail while the other two use the simulation model, CMLS, to calculate the time required for the chemical to reach a given soil depth and the amount of chemical leaching past a specified soil depth. The CHEMRANK software includes data management features.
CMLS D.L. Nofziger, A.G. Hornsby (1985)	Soil Science Department University of Florida Gainesville, Florida 32611	Chemical Movement in Soil (CMLS) calculates the amount of pesticide leaching past a 60-cm root zone for any given amount of time. The model includes graphical displays representing the relative amount of the chemical remaining in the soil as a function of time. The model also accounts for soils with 20 layers or horizons, and enables the user to enter partition coefficients and degradation half-lives of the chemical of interest for each horizon. The model requires input of daily rainfall data.

Table 3-3. Description of Ground Water Vulnerability Methods (continued) (adapted from EPA, 1993)

Name of Method Author(s) and date:	Contact Address	Method Description
GLEAMS W.G. Knisel, R.A. Leonard (1980)	U.S. Department of Agriculture, Southeast Watershed Research Laboratory Coastal Plain Experimental Station P.O. Box 946 Tifton, Georgia 31793	This model evaluates the effects of agricultural management practices on transport of pesticides in the root zone. The model incorporates rainfall, infiltration, and runoff. The model solves a one dimensional transient convective-dispersive equation for solute transport using a simplified water balance. It can also calculate the movement and transformation of nutrients.
GUS D.I. Gustafson (1989)	GUSWORK - INC. P.O. Box 16081 115 Bolton Place Chapel Hill, NC 27516	The Ground Water Ubiquity Score (GUS) method calculates a GUS index. The ground water ubiquity system is a numerical continuum scale that divides pesticides into non-leachers, transitionals, and leachers. A zone is designated on the GUS scale for each class of pesticides. The GUS index is based on curve fittings between pesticide half-lives and K_{oc} values.
Ground Water Contamination Likelihood P.S.C. Rao (1985)	Department of Agricultural Engineering University of Hawaii at Manoa Honolulu, Hawaii 96822	This method is based on surface soil horizon and pesticide parameters. The method calculates a continuous numerical index via a multiplicative exponential model.
Jury's Benchmark Approach W.A. Jury, W.F. Spencer, W.J. Farmer (1983 and 1984)	Department of Soil and Environmental Sciences University of California Riverside, California 92521	This approach uses a series of indices to rank pesticides according to their potential to volatilize, leach, and degrade in soil. They presented indices to define convective velocity and diffusion that incorporate pesticide, hydrogeologic, and climatic factors.
LEACH Index D.A. Laskowski, C.A.I. Goring, P.J. McCall, R.L. Swann (1982)	DOWELANCO 306 Building A2-723 9410 Zionsville Road Indianapolis, IN 46268-1053	This method uses a benchmark approach incorporating the effects of pesticide solubility and persistence on leaching. It accounts for four pesticide chemical properties: 1) mass per volume; 2) degradation half-life; 3) vapor pressure; and 4) sorption coefficient.

Table 3-3. Description of Ground Water Vulnerability Methods (continued) (adapted from EPA, 1993)

Name of Method Author(s) and date:	Contact Address	Method Description
LEACHM R.J. Wagenet, J.L. Hutson (1986)	Department of Agronomy Cornell University Ithaca, New York 14853	LEACHM is a finite-difference model for simulating the pesticide fate in the unsaturated zone. The model includes options for Freundlich sorption and kinetic linear (two-site) sorption, and provides for simulating transport in soil columns under steady-state and interrupted steady-state flow. It can simulate the effects of layered soils, precipitation/evapotranspiration cycles, plant growth, and the transport of parent pesticides and multiple metabolites. LEACHM is the only generally available one-dimensional unsaturated zone model which solves the water balance using Richard's equation. The model also includes an option for capacity flow. If the appropriate rate constant is entered, the model can simultaneously predict concentrations of the parent compounds and metabolites. LEACHM does not consider the effects of management practices, surface hydrology, and erosion processes.
Montana Relative Aquifer Vulnerability Evaluation (RAVE) T. DeLuca, P. Johnson (1990)	Montana Department of Agriculture Environmental Management Division Helena, Montana 59602-0205	This method consists of a numeric scoring system based on nine factors. The RAVE score is intended for on-site determinations.
MOUSE S. Pacenka (1984)	Center for Environmental Research Cornell University Ithaca, New York 14853	MOUSE is a set of mathematical models for tracing the transport and fate of pesticides in the unsaturated and saturated zones. It is used as a preliminary management tool in different soil-climate-management regimes. MOUSE has four submodels: 1) climatic data generator; 2) vadose zone water balancer; 3) vadose zone solute transporter; and 4) aquifer water and solute transporter.

Table 3-3. Description of Ground Water Vulnerability Methods (continued) (adapted from EPA, 1993)

Name of Method Author(s) and date:	Contact Address	Method Description
OPUS R.E. Smith, V.A. Ferreira (1988)	U.S. Department of Agriculture Northern Plains Area Ft. Collins, Colorado 80522	OPUS consists of a computer simulation model of an agricultural system. The model simulates relative hydrogeologic erosion and chemical fate results from various management and climate scenarios. The objective of this model is to indicate system response relative to various management practices. OPUS operates on various time scales and may be used in various types of agricultural studies. The required inputs include a numerical description of topography, soils, climate, initial conditions, and management practices. Processes simulated by OPUS include hydrology (runoff, soil-water flux and evapotranspiration), erosion, management, crop growth, and agricultural chemicals. OPUS generates user specified output.
PATRIOT J.C. Imhoff, P.R. Hummel, J.W. Kittle, R.F. Carsel	U.S. EPA, Robert S. Kerr, Environmental Research Lab. Ada, Oklahoma 74820	PATRIOT is a dynamic modeling system consisting of a combined flow and transport model (PRZM-2); national-scope data bases for rainfall, soils geographic occurrence, soil properties, pesticide properties and cropping practices; data base management; a soil water retention parameter estimator; and ranking procedures for comparing leaching potentials for various combinations of geologic materials to the water table.
PESTANS I G.G. Enfield, R.F. Carsel, S.Z. Cohen, T. Phan, D.M. Walters (1982)	U.S. EPA, Robert S. Kerr, Environmental Research Lab. Ada, Oklahoma 74820	PESTANS I is one-dimensional, steady-state model that is limited to projecting vertical movement through the unsaturated zone. It is computationally simple to run and is used to evaluate the relative ground water contamination potential of various pesticides. Although the model requires very little input data, net recharge velocity may be difficult to estimate.

Table 3-3. Description of Ground Water Vulnerability Methods (continued) (adapted from EPA, 1993)

Name of Method Author(s) and date:	Contact Address	Method Description
PESTANS II G.G. Enfield, R.F. Carsel, S.Z. Cohen, T. Phan, D.M. Walters (1982)	U.S. EPA, Robert S. Kerr, Environmental Research Lab. Ada, Oklahoma 74820	PESTANS II is a two-dimensional transient numerical model that predicts both horizontal and vertical movement of water and pesticides. This model allows the user to vary degradation rates and soil absorption with depth. Additional input data on water flux and soil characteristics in the model allow separate predictions of the rate of leaching through the root zone and the vadose zone, as well as calculations of concentrations in the saturated zone. PESTANS II requires much more hydrogeologic input data, is more complex to run, and requires considerably more computational time than PESTANS I.
PRZM R.F. Carsel, L.A. Mulkey, M.N. Lorber, L.B. Baskin (1985)	U.S. EPA, Environmental Research Laboratory Athens, Georgia 30163	PRZM is a one-dimensional, dynamic, continuous, mechanistic, pesticide transport model. PRZM requires two input files, one containing hydrology, crop, pesticide, and soil information, the other containing daily meteorological data. PRZM has been modified to include a stochastic (probabilistic) solution. The model provides concentrations or masses of pesticides expressed in fluxes or in accumulated quantities leaving a defined depth, respectively.
PRZM-2 J.A. Mullins, R.F. Carsel, J.E. Scarbrough, A.M. Ivery (1993)	U.S. EPA, Environmental Research Laboratory Athens, Georgia 30163	PRZM-2 is a union of PRZM (see above) and VADOFT. VADOFT is a one-dimensional, finite-element, flow and transport model. It simulates the movement of water and chemicals within the soil profile from the bottom of the root zone to the top of the water table.
RZWQM D.G. DeCoursey, K.W. Rojas (1989) L.R. Ahuja, D.G. DeCoursey, J.D. Hanson, C.S. Hebsom, R. Nash, K. Rojas, and M.J. Shaffer (1992)	U.S. Department of Agriculture ARS P.O. Box E Colorado State University Fort Collins, Colorado 80522 and U.S. Department of Agriculture Durant, Oklahoma 74701	The Root Zone Water Quality Model (RZWQM) is a physical process model that simulates the movement of water, nutrients, and pesticides over and through the root zone at a representative location within a field. The model simulates the following processes: physical (hydrology/hydraulics of water and solute transport), nutrient, pesticide plant growth, management and soil chemistry. The use of this model has shown the need for a thorough evaluation of soil properties and their relation to macropore flow.

Table 3-3. Description of Ground Water Vulnerability Methods (continued) (adapted from EPA, 1993)

Name of Method Author(s) and date:	Contact Address	Method Description
SESOIL M. Bonazountas, J. Wagner (1984) and P. Harrigan, A. Nold (1989)	ADL, Inc. Cambridge, Massachusetts 02140 or U.S. EPA Office of Toxic Substances Washington, D.C. 20460	The Seasonal Soil Compartment (SESOIL) model was developed for long-term environmental hydrologic, sediment, and pollutant fate simulations. The physical setting is depicted as four distinct unsaturated soil layers or compartments, each having uniform properties. The model simulates the chemical transport and fate processes of leaching, volatilization, hydrolysis, and biodegradation. The model can describe water transport, pollutant transport and transformation, soil quality, pollutant migration to ground water, and other processes. It can provide the distribution of the chemical in the soil column which extends from the ground surface to the lower end of the unsaturated soil layer. The model has been tested and evaluated.
SPISP Don Goss (1991)	Texas A&M University Blackland Research Center 808 East Blackland Road Temple, Texas 76502	The Soil/Pesticide Interaction Screening Procedure (SPISP) categorizes estimated pesticide losses three ways: 1) leached; 2) absorbed runoff; and 3) solution runoff. The model uses algorithms based on soil properties to group soils into four loss potentials for leaching and three loss potentials categories for runoff. In addition, the model uses algorithms based on pesticide properties. The soil and pesticide groupings are combined in a matrix to give an overall loss potential: high, intermediate or low. This potential is a first time evaluation of the impact of using a particular pesticide on a specified soil.
VIP J.E. McLean, R.C. Sims, W.J. Doucette, C.R. Caupp, W.J. Grenney (1988)	Utah Water Research Laboratory Utah State University Logan, Utah 84322	The VIP model involves numerical solution algorithms and nonequilibrium kinetics to describe the behavior of pesticides in the unsaturated zone and predict pesticide mass transport to the atmosphere and ground water.

Table 3-3. Description of Ground Water Vulnerability Methods (continued) (adapted from EPA, 1993)

Name of Method Author(s) and date:	Contact Address	Method Description
VULPEST J.P. Villeneuve, D. Banton, P. Lafrance (1987 and 1990)	Université du Québec Institute National de la Recherche P.O. Box 7500 Scientifique Sainte-Foy Québec, Canada G1Z4C7	The VULPEST model uses the deterministic adjective dispersion equation and the Monte Carlo stochastic approach to evaluate ground water contamination by pesticides. VULPEST has been used as a management tool to permit the best use of pesticides in association with a ground water protection scheme. The model accounts for the characteristics of nonpoint source contamination and provides a set of probabilistic results. Results obtained from VULPEST include the maximum concentration, the average annual concentration and the cumulative mass for each Monte Carlo simulation. A stochastic breakthrough curve corresponding to the integration over time of the breakthrough curves is also obtained from each Monte Carlo simulation. The model is reported as a useful tool in identifying vulnerable sites and quantifying the type and rate of pesticide that can be applied to minimize the risk of contamination.

3.1.2 Selection of Sensitivity/Vulnerability Assessment Methods

It is beyond the scope of this document to recommend one sensitivity/vulnerability method over another, or to define selection criteria that would be appropriate for all situations. The selection of an appropriate aquifer sensitivity or ground water vulnerability method will depend on a number of implementation, technical, policy, and financial considerations unique to each State or locality. These factors include:

- Ability of the method to accurately assess aquifer sensitivity;
- Applicability of the method to local conditions and available data;
- Costs of implementing the method;
- Other potential uses or benefits of the information collected;
- Status of method development;
- Data requirements;
- Relative degree of confidence in a particular method (prior validation or field verification);
- Ease of use in applying the method to the conditions of the State;
- Level of expertise needed versus available staff;
- The degree of technical guidance and data which is available for more complex methods;
- State policies and statutes and the objectives of the aquifer sensitivity/vulnerability study (e.g., data quality objectives); and
- Appropriate spatial scales to use in sensitivity/vulnerability assessments (e.g., large areas such as counties or field-level assessments).

For a more detailed discussion of management and technical information to assist States in selecting aquifer sensitivity or ground water vulnerability assessment methods, see EPA's Ground Water Protection Division's TAD, A Review of Methods for Assessing Aquifer Sensitivity and Ground Water Vulnerability to Pesticide Contamination (U.S. EPA, 1993).

3.1.3 Documentation and Evaluation of Sensitivity/Vulnerability Assessment Methods

This section discusses selected studies and documents that provide technical information on aquifer sensitivity and ground water assessment methods and on the evaluations of these methods. Some of the sources referenced in this section are ongoing and are scheduled to be released in the near future.

EPA's Ground Water Protection Division's TAD, A Review of Methods for Assessing Aquifer Sensitivity and Ground Water Vulnerability to Pesticide Contamination (U.S. EPA, 1993) summarizes aquifer sensitivity and vulnerability methods. The purpose of the TAD is to provide States with the technical information needed to select an appropriate assessment method. Information for the TAD was assembled from a literature search of available methods, technical committee meetings, and a workshop.

The Water Science and Technology Board (WSTB) of the National Research Council convened a committee that evaluated the current techniques for assessing ground water vulnerability.[2] The evaluation results were published in Ground Water Vulnerability Assessment: Predicting Relative Contamination Potential Under Conditions of Uncertainty (December 1993). This report summarizes the classes of ground water assessment methods and provides information on analytical approaches and data requirements. In addition, the report provides information about factors that contribute to ground water contamination and has applications in regional ground water assessments, site specific screening and planning, and also can be used in a variety of regulatory programs. The report is intended for federal and State regulatory planning authorities, consultants, academia, researchers, and public interest groups. The U.S. EPA, USDA, and the U.S. Bureau of Reclamation sponsored the study and report.

The Phase II Report of the National Survey of Pesticides in Drinking Water Wells, released, January 1992, provides an assessment of the use of Agricultural DRASTIC. EPA used DRASTIC to estimate ground water vulnerability to stratify the Survey. The Phase II analysis concluded that "DRASTIC did not function effectively when measured at the county level to predict drinking water wells which may contain pesticides or nitrate." In addition, subcounty DRASTIC scores showed inconclusive results similar to the county-level results. The Phase II Report lists several factors that may have affected the ability of DRASTIC, as it was applied in the Survey, to identify wells containing pesticides. Three possible causes were noted: (1) DRASTIC was applied to areas the size of counties, although it was not designed to yield a single numeric vulnerability score for an area of that size; (2) the level of effort devoted to county-level scoring may have not yielded sufficiently detailed data upon which to base scoring; and (3) DRASTIC variables may have been measured on too gross a scale relative to well sites. For more information

[2] Further information may be obtained from the Committee on Techniques for Assessing Ground Water Vulnerability, National Academy of Sciences, 2101 Constitution Avenue, N.W., Washington, D.C. 20418; Telephone: (202) 334-3422.

refer to the Phase II Report of the National Survey of Pesticides in Drinking Water Wells (1992).

EPA's Office of Research and Development (ORD) and its Region III office completed a project to test the performance of the DRASTIC classification system and the seven DRASTIC elements to predict the occurrence of pesticides and nitrate in shallow ground waters. In this project, ground water samples were drawn from a large network of wells located on the Delmarva peninsula, comprised of parts of the States of Delaware, Maryland, and Virginia. The U.S. Geological Survey (USGS) National Water Quality Assessment (NAWQA) Study project cooperated in this test.[3]

In 1990, the U.S. Environmental Protection Agency initiated a pollution prevention program to explore innovative ideas and new technologies. This project, *Prevention of Ground-Water Contamination from Pesticides: Assessment and Information Tools for State Use*, was a cooperative effort between the Office of Research and Development (ORD), the Office of Pesticide Programs, and EPA Region 3. The purpose of this project was to assemble technical tools and information systems that states could use in developing the Pesticide State Management Plans described in OPP's Pesticides in Ground Water Strategy. This report presents a summary and analysis of the five environmental management tools produced by this project. These tools were designed to be used individually or in conjunction with one another to help state ground-water resource managers assess the vulnerability of ground water to pesticide contamination. The five tools that were analyzed are listed below:

(1) Pesticide Assessment Tool for Rating Investigations of Transport (PATRIOT)

(2) Pesticide Usage Management Planning System (PUMPS)

(3) Delmarva Peninsula Project

(4) Iowa Screening Concepts Project

(5) Pesticide Information Network (PIN)

This report introduces each information product, describes the purpose and scope of each, lists information resources for obtaining full reports and access to software, and briefly describes the methodology, utility, and limitations of each tool. The report also

[3] The U.S. Geological Survey Circular 1080: Are Fertilizers and Pesticides in the Ground Water? A Case Study of the Delmarva Peninsula, Delaware, Maryland, and Virginia. U.S. Geological Survey, 1992, provides a non-technical description of the key findings of the NAWQA study. For more recent information on this study, contact the Ground Water Protection Section, Drinking Water/Ground Water Protection Branch, Water Management Division, U.S. EPA Region 3, 841 Chestnut Building, Philadelphia, PA 10107; Telephone: (215) 597-2786.

briefly discusses considerations for using the products in the inter-related steps that make up an integrated ground-water vulnerability assessment strategy. Ground-water resource managers can make use of these tools to design and implement effective and efficient ground-water assessment and monitoring strategies for protecting ground water from contamination by pesticides. Copies of the report will be available in September 1994 from EPA's Office of Pesticide Programs; contact Constance Haaser at (703) 305-5458 for further information.

3.2 Pesticide Use Evaluations

Understanding where and how a pesticide is used is central to the development of an effective pesticide management plan. Both a Generic and a Pesticide SMP should describe the sources of basic information concerning pesticide usage in the State that a State plans to use. For a Pesticide SMP, the State also must indicate the sources of data it has available on the particular pesticide in question, including geographic use, application rates, application timing, and application method. If data is not available, the State can describe the method and timetable it is planning to follow to collect such data. This section describes some of the basic sources of pesticide use and cropping practices information.[4]

The 1990 Farm Bill P.L. 101-624 1990 established the Agricultural Water Quality Protection Program as a voluntary incentive program to encourage agricultural producers in environmentally sensitive areas to develop and implement on-farm water quality protection and source reduction plans. These agricultural water quality protection plans should include (as applicable): 1) relevant information concerning the protection of the water quality of the farm, 2) specific water quality protection goals along with agricultural and water quality practices that will be avoided or carried out to ensure compliance with environmental laws, and 3) information to enable the evaluation of the plan and recommendations of application rates and disposal methods. Under this program, farm owners and operators enter into three- to five-year agreements with USDA to carry out the plans. In addition, participants must annually supply production figures, well test results, soil tests, tissue tests, nutrient application levels, pesticide application levels, and animal waste usage levels to their USDA Soil Conservation State office. Participating farm owners and operators must also provide USDA with usage rates on nutrients, pesticides, and animal waste materials for the three years prior to enrollment in the program.

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[4] An interagency planning group on pesticide-use data has been in operation since 1981. The planning group is coordinated by EPA and includes representatives of USDA, the Food and Drug Administration (FDA), U.S. Bureau of Census, and some States. The group meets several times per year to identity usage data needs and to coordinate information collection/dissemination efforts. Further information on the Interagency Pesticide Usage Data Planning Group may be obtained from Arnold L. Aspelin, Economic Analysis Branch, Biological and Economic Analysis Division (7503W), Office of Pesticides and Toxic Substances, U.S. EPA, 401 M Street, S.W., Washington, D.C. 20460; Telephone: (703) 308-8136.

3.2.1 Pesticide-Use Profiles Based on Sales or Crop Data

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) requires EPA to register pesticides. These federal registrations are accessible using the National Pesticide Information Retrieval System (NPIRS) data base. Individual State registration data can also be obtained from NPIRS. A pesticide listed on NPIRS does not automatically mean it has a federal registration.

Estimating for agricultural field use of pesticides, several techniques are available based on sales estimates and a knowledge of regional agronomic practices. Sales estimates are updated annually through joint efforts of State departments of agriculture, the USDA Economic Research Service (ERS), and the USDA National Agricultural Statistics Service (NASS). NASS also maintains State statisticians who provide State-level and sometimes county-level information on agricultural production. The spatial resolution of this information is variable, however, and may not be sufficient for reliable ground water vulnerability determinations in some areas.

The USDA Agricultural Research Service (ARS) and Cooperative Extension Service, in conjunction with researchers at State land grant universities and State cooperative extension services, are good sources of information on regional agronomic practices. These groups make recommendations to farmer-operators on pesticide application rates and techniques for most common crops. Such recommendations are generally published in a variety of technical bulletins, or in more general interest publications for distribution to the user community (USDA Water Quality Initiative Team, 1990). County agricultural extension agents are familiar with local cropping practices and the recommended pesticide usage for their localities.

> The pesticide-use approach utilized by Gianessi and Puffer (1990) included an equation of the following form:
>
> Pesticide use (pounds of active ingredients) = A x B x C, where
>
> A = Harvested acres planted of specific crops,
>
> B = Percent (as a fraction) of harvested acres receiving pesticide applications each year, and
>
> C = Typical application rate (pounds of active ingredient/acre/year).
>
> An example of applying such estimation techniques for counties within the **State of North Carolina** is provided in Moreau and Danielson (1990). The National Oceanic and Atmospheric Administration has also used such estimation techniques for 78 estuarine drainage areas rimming the contiguous United States (Piat et al., 1989).

Studies conducted by the National Center for Food and Agricultural Policy (formerly Resources for the Future) (Gianessi, 1986; and Gianessi and Puffer, 1988, 1990, and 1991) combined production and agronomic information to assemble a national-level data base of estimated agricultural pesticide use, turf pesticide use (i.e., golf courses), urban use, as well as estimates of herbicide use.

The level of spatial resolution using pesticide use profiles based on sales or crop data depends on the reliability of production statistics and agronomic information. Production statistics generally result in State-level estimates. As the spatial resolution moves down to the county level, production statistics are generally based on a small number of data collection points within each county. Where the types of crops grown are highly uniform (e.g., winter wheat in Kansas), the county-level figures may be adequate for determining ground water vulnerability. Where a county shows a diversity of crops and cropping systems, county-level production figures should be used with greater caution.

States seeking detailed spatial production statistics may be able to obtain records down to the individual farmer-operator level. The USDA Soil Conservation Service (SCS) and Agricultural Stabilization and Conservation Service (ASCS) sometime track land uses down to the farmer-operator level in response to requirements under the 1985 Food Security Act (usually called the Farm Bill). The ASCS, which disburses a variety of commodity support payments, maintains detailed data on a limited number of crops grown by farmer-operators in some areas. The SCS and ASCS use these detailed data sources to generate summaries at county or State levels. The main limitation on the availability of detailed data (in addition to laws regarding individual landowner confidentiality) may be the extent to which farmers in a region participate in Farm Bill commodity programs. There are no commodity supports for many types of crops, and therefore the data collected by SCS and ASCS may be sparse in some areas.

The SCS and ASCS maintain local offices that work closely with State organizations such as soil and water conservation districts and county extension offices. In addition, State departments of agriculture often have district or regional field inspectors who provide valuable insights based on their best professional judgment (BPJ). Where not accompanied by organized survey or official recordkeeping procedures, these BPJ approaches are best viewed as an indirect approach. However, they remain a good means of supplementing the more readily available published information or to make estimates of pesticide use at the sub-county level.

3.2.2 Voluntary User Surveys

Select pesticide use data are available from pesticide user surveys. The USDA's ERS/NASS began a major pesticide usage data collection program in 1990 as part of the President's Water Quality Initiative and Food Safety Initiative. Under this program NASS, in conjunction with State departments of agriculture, annually survey farmers to gather pesticide usage data for select field crops, fruits, vegetables, and nuts. USDA published a 1990 Field Crop Summary (March 1991) and a Vegetable Summary (June 1991). Each summary includes crop data on the

> In 1984, the **State of Maine** began a program of surveying pesticide use. The State updates the survey annually. The goal is to build county pesticide use profiles and describe application methods and cropping practices in Maine (Maine Board of Pesticides Control, 1990).

quantities of pesticides applied, application rates, and application frequency for the major producing States. For the most part, the pesticide data collected are reliable for estimate State level usage. Depending upon funding, USDA plans to continue these annual voluntary pesticide usage data surveys and expand the survey to include more crops and cover a greater production area.

In recent years, the USDA National Agricultural Pesticide Impact Assessment Program (NAPIAP) has given States grants to conduct pesticide-use and benefits studies. Chapter 7 provides contact information for NAPIAP State liaisons.

3.2.3 Commercial Pesticide Usage Surveys

A wide range of agricultural and nonagricultural pesticide-use data are available for a fee from commercial market research organizations. A number of firms regularly conduct pesticide-use surveys either on a multi-client subscription basis or for hire on a proprietary bases. Such services are often utilized by major pesticide producing and vary greatly in survey approach, sites covered, geographic specificity, statistical validity, and various details of actual pesticide-use. Commercial survey firms also conduct studies on a custom basis to meet client needs. In the case of custom/proprietary studies, the results are generally only available to the sponsoring organization. Table 3-4 provides information on some commercial market survey organizations. Mention of these organizations does not constitute their endorsement by the United States government.

Table 3-4. Examples of Information Available from Some Commercial Market Survey Organizations

Organization	Type of Data
Kline and Company, Inc. Fairfield, New Jersey	Commercial and Professional Markets for Pesticides and Fertilizers
Maritz Marketing Research Inc. Fenton, Missouri	Specialty Crop Study Pesticide Use Study
Doane Agricultural Services St. Louis, Missouri	Tillage and Cultural Practices
Technomic Inc. Chicago, Illinois	Ornamentals, Sugar Beets, Biotechnology, and Pest Control
National Center for Food and Agricultural Policy Washington, D.C.	Insecticide and Fungicide Data Bases

3.2.4 Required Recordkeeping

EPA certification regulations require that all commercial certified applicators maintain pesticide-use records for restricted-use pesticides. Some States have promulgated more comprehensive regulations, adding reporting requirements, recordkeeping requirements for general-use pesticides, and recordkeeping requirements for private certified applicators.

In some cases, records, required for restricted-use pesticides support SMP assessment and planning. The 1990 Farm Bill includes a provision requiring documentation of the use of restricted-use pesticides. These records may be comparable to those already maintained by commercial certified applicators in each State. Under this provision, each farmer who applies restricted-use pesticides must maintain records of their use. Federal agencies may obtain access to restricted-use pesticide records through the USDA. State agencies may obtain access to these records through the State lead agency for pesticides. (7 U.S.C.A. §136i-1(b))

Many States require pesticide recordkeeping at the point-of-sale or for end users. These records may include a broad range of data. Table 3-5 provides information on the recordkeeping requirements for certified applicators of restricted-use pesticides in 43 States. A more detailed summary of California's recordkeeping requirements is provided in Table 3-6.

3.2.5 Nonagricultural Use Considerations

Because pesticides are also used for nonagricultural purposes, SMPs should explain how information on the extent and types of such uses will be obtained. Some or all of the following nonagricultural uses of pesticides (U.S. EPA, 1987) should be considered. The types of uses each State considers will depend on its unique characteristics. These uses include:

- Ornamental lawns and turf (e.g., golf courses);
- Ornamental shrubs and vines;
- Right of way maintenance;
- Pest control for household, domestic, and institutional dwellings and industrial sites;
- Processed nonfood products, such as textiles and paper; and
- Aquatic sites, including canals and lakes.

Table 3-5. Recordkeeping Requirements for Certified Applicators of Restricted Use Pesticides*

State	Product Name	Formu-lation	EPA Reg. No.	Amount Applied	Rate Applied	Location	Treated Area	Target Pest	Crop or Stored Product	Method Applied	Date Applied	Applicator Name/ Address	Applicator Cert. No.	Recording Deadline	Record Retention
** Alaska	-	✓	✓	-	-	✓	-	✓	✓	-	✓	✓	-	-	✓
Arizona	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	✓	✓	✓	-	✓
Arkansas												-			
California	✓	-	✓	✓	-	✓	✓	-	✓	-	✓	✓	-	-	✓
** Colorado	✓	✓	✓	✓	✓	✓	-	✓	✓	-	✓	-	-	-	-
** Connecticut	✓	-	✓	✓	-	✓	✓	✓	✓	-	✓	✓	✓	-	5 years
** Delaware	✓	✓	-	-	✓	✓	-	✓	-	-	✓	✓	-	-	✓
Florida	✓	-	-	✓	✓	✓	-	-	✓	✓	✓	-	-	-	✓
Hawaii	✓	✓	✓	✓	-	✓	✓	✓	-	-	✓	✓	✓	-	✓
** Illinois	✓	-	✓	-	✓	✓	-	-	-	-	✓	-	-	-	✓
** Indiana	✓	-	✓	✓	-	✓	✓	✓	✓	-	✓	✓	✓	-	✓
** Iowa	✓	-	-	✓	✓	✓	-	-	-	-	✓	✓	✓	-	3 years
** Kansas	✓	✓	-	✓	✓	-	-	✓	-	-	✓	✓	✓	-	-
Kentucky	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Maine	✓	-	-	✓	✓	✓	✓	✓	-	✓	✓	✓	-	-	-
Maryland	✓	✓	-	✓	✓	✓	-	✓	✓	✓	✓	✓	-	-	2 years
Massachusetts	✓	-	✓	✓	-	✓	-	✓	✓	✓	✓	✓	-	-	3 years

* Derived from survey conducted by the State of Maryland in 1990. States Not Responding: Alabama, Georgia, Idaho, Louisiana, Mississippi, Nebraska, New York, Vermont, District of Columbia, and the Virgin Islands.

** Requirements for Commercial Restricted-Use Pesticide applicators only.

Table 3-5. Recordkeeping Requirements for Certified Applicators of Restricted Use Pesticides* (continued)

State	Product Name	Formu-lation	EPA Reg. No.	Amount Applied	Rate Applied	Location	Treated Area	Target Pest	Crop or Stored Product	Method Applied	Date Applied	Applicator Name/ Address	Applicator Cert. No.	Recording Deadline	Record Retention
Michigan	✓	✓	-	✓	✓	✓	-	✓	-	✓	✓	-	-	-	3 years
Minnesota	✓	✓	✓	✓	-	✓	✓	-	-	-	✓	✓	✓	Day Applic.	5 years
Missouri	Operational recordkeeping requirements for certified commercial or noncommercial applicators not specified for this State.														
Montana	✓	✓	✓	-	✓	✓	✓	✓	✓	✓	✓	✓	-	24 hours	2 years
Nevada	✓	✓	-	✓	✓	✓	-	✓	✓	✓	✓	✓	-	-	2 years
** New Hampshire	✓	✓	-	✓	-	✓	✓	✓	✓	-	✓	✓	-	7 days	2 years
New Jersey	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	-	-	-	2 years
New Mexico	✓	✓	✓	✓	-	✓	-	✓	✓	-	✓	✓	-	-	2 years
***North Carolina	✓	-	✓	-	✓	✓	✓	-	✓	-	✓	-	-	-	3 years
** North Dakota	✓	✓	-	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Day Applic.	-
** Ohio	✓	✓	-	✓	✓	✓	-	✓	-	✓	✓	✓	-	Day Applic.	3 years
Oklahoma	✓	✓	✓	✓	✓	✓	-	✓	-	-	✓	✓	-	-	2 years
** Oregon	✓	✓	-	✓	✓	✓	-	-	✓	✓	✓	Name Only	-	-	3 years
Pennsylvania	✓	✓	-	✓	✓	✓	-	-	✓	-	✓	Name Only	✓	-	3 years
** Puerto Rico	✓	✓	-	✓	-	✓	-	-	-	✓	✓	-	-	-	2 years
** Rhode Island	✓	-	-	✓	-	-	-	-	-	-	✓	✓	✓	-	2 years
South Carolina	-	undetermine	-	-	-	-	-	-	-	-	-	-	-	-	-

* Derived from survey conducted by the State of Maryland in 1990. States Not Responding: Alabama, Georgia, Idaho, Louisiana, Mississippi, Nebraska, New York, Vermont, District of Columbia, and the Virgin Islands.

** Requirements for Commercial Restricted-Use Pesticide applicators only.

*** North Carolina has requirements for commercial aerial applicators (all pesticides) and commercial ground applicators (restricted use pesticides only). No requirement exists for certified private applicators to keep records.

Table 3-5. Recordkeeping Requirements for Certified Applicators of Restricted Use Pesticides* (continued)

State	Product Name	Formu-lation	EPA Reg. No.	Amount Applied	Rate Applied	Location	Treated Area	Target Pest	Crop or Stored Product	Method Applied	Date Applied	Applicator Name/ Address	Applicator Cert. No.	Recording Deadline	Record Retention
**South Dakota	✓	✓	-	✓	-	✓	✓	✓	✓	✓	✓	✓	-	-	-
**Tennessee	✓	-	-	✓	✓	✓	-	✓	✓	-	✓	✓	-	-	2 years
Texas	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	-	-	-
**Utah	✓	✓	-	✓	✓	✓	-	-	-	-	✓	-	-	-	2 years
**Virginia	✓	-	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	2 years
Washington	✓	-	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	7 years
**West Virginia	✓	✓	-	✓	✓	✓	-	✓	-	-	✓	Name Only	-	-	-
**Wisconsin	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Name Only	-	-	2 years
Wyoming	✓	✓	✓	✓	✓	✓	-	✓	✓	-	✓	-	-	-	-

* Derived from survey conducted by the State of Maryland in 1990. States Not Responding: Alabama, Georgia, Idaho, Louisiana, Mississippi, Nebraska, New York, Vermont, District of Columbia, and the Virgin Islands.

** Requirements for Commercial Restricted-Use Pesticide applicators only.

Table 3-6. Summary of Required Pesticide Sale and Use Recordkeeping in California

Recordkeeping Required for	Records Maintained on	Record Content	Exclusions
Licensed Pesticide Dealers	• Pesticides Sold/Delivered	• Name and address of purchaser • Quantity and type purchased • Agricultural Pest Control Adviser recommendation • Delivery location • Person/business receiving shipment	Home use
	• Records submitted by purchasers • Restricted-use pesticides • Known leachers	• Signed statement, permits • Certified applicator number	None
Pesticide Users	• Pesticides used for agriculture, rights-of-way, golf courses, cemeteries • Restricted-use pesticides • Industrial post-harvest commodity pesticide use • Pest control businesses • Suspected leachers used for outdoor industrial or institutional treatment	• Application date and amount applied • Operator name • Location of use • Crop or site treated • Size of treated area • Pesticide name and registration number *Additional requirements for agricultural property operators and agricultural pest control businesses:* • Treated location (county, township, range, section, base meridian) • Hour treatment completed • Operator and site identification numbers • Name of application supervisor	Livestock

Table 3-6. Summary of Required Pesticide Sale and Use Recordkeeping in California (continued)

Recordkeeping Required for	Records Maintained on	Record Content	Exclusions
Property Operators	• Pesticide applications where re-entry intervals exceed "spray is dry/dust is settled" requirement	• Crop and acreage • Pesticides used • Dosage, dilution rate, and volume per acre • Date application completed	None
Agricultural Pest Control Advisors	• Ground water protection advisories	• Operator of treated property • Address of operator • Treated property location (base meridian, township, range, section) • Soil textural class of treated property • Property map indicating such features as active and abandoned wells (domestic, irrigation, drainage) • Treatment conditions that will minimize potential for ground water contamination • Signature and address of Pest Control Advisor	None

Table 3-6. Summary of Required Pesticide Sale and Use Recordkeeping in California (continued)

Recordkeeping Required for	Records Maintained on	Record Content	Exclusions
Agricultural Pest Control Advisors (continued)	• Written Recommendations	• Pesticide name, dose, and recommended application method • Pest to be controlled • Owner/operator, location, and acreage of treated site • Crop, commodity, or site • Application schedule or conditions • Warning of potential damages • Signature, address, date, and affiliation of person making recommendation • Worker re-entry interval, if established • Label restrictions on use of disposition of treated commodity or area • Criteria for determining the need for treatment	None

Table 3-6. Summary of Required Pesticide Sale and Use Recordkeeping in California (continued)

Recordkeeping Required for	Records Maintained on	Record Content	Exclusions
Agricultural Pest Control Businesses	• Pesticide Applications[1]	• Name of property owner/operator • Property location • Date and time of notification • Notification method and person notified	None
Agricultural Property Operators	• Pesticide Applications[2]	• Property location, site identification number, and acreage • Pesticides applied • Date and time application completed • Applicable re-entry intervals	• Re-entry intervals excluded if operator received written recommendation from Pest Control Advisor

1. Reported to property owner/operator within 24 hours of application completion.

2. Maintain records of pesticide application notices by site treated.

A range of recordkeeping requirements is illustrated by the different system in use in two States:

- **California**'s system of Pesticide Management Zones (PMZs) allows the continued use of pesticides with the potential to pollute ground water within specified areas provided the use is subject to strict safeguards. These safeguards include detailed recordkeeping by pesticide dealers (who are required to obtain signed statements from purchasers of certain restricted-use pesticides that have been found in ground water (i.e., known leachers)). These statements indicate whether the materials will be used within a PMZ. Dealers must verify that the purchaser has the required permits and must submit quarterly sales reports for all uses of known leachers to the California Department of Pesticide Regulation (CDPR). The end user must have a permit to use those restricted use pesticides within a PMZ. A certified applicator (commercial or private) is required to apply known leachers both inside and outside PMZs. Farmer-operators as well as licensed applicators are required to maintain records of their pesticide use. Table 3-6 summarizes the pesticide sale and use recordkeeping requirements that relate to minimizing the potential for ground water contamination in California.

- **Maine**'s SMP approach includes a system of Limited Use pesticides. Once a pesticide is classified as Limited Use, the sale and use is restricted to licensed persons with a permit granted by the State's Board of Pesticide Control (BPC). To obtain a permit, applicants are required to provide BPC with the following information for each pesticide:

  - Name of applicator and/or landowner;
  - Description of soils;
  - Map of use area noting locations of surface waterbodies, springs, and bedrock or ledge protrusions;
  - Rate, timing, and methods of application; and
  - Description of current or proposed wellhead setback or other ground water protection measures.

- In 1989, **Maine** initiated requirements for point-of-sale recordkeeping for all general-use pesticides (Maine Board of Pesticides Control, 1990). In conjunction with existing requirements for restricted-use pesticides, this requirement helps in generating actual quantity of use data for Maine's current list of approximately 5,200 registered pesticides. Although these sales reporting procedures do not necessarily identify the areas where the products are used, the data provides checkpoints to compare end-user surveys and estimates based on indirect techniques. Requiring some recordkeeping for general-use pesticides makes it easier to estimate pesticide use in urban areas for homes and golf courses.

EPA has a program of conducting pesticide usage surveys for the urban/nonfarm sectors. The survey results provide national and some regional information on the products used, use practices, disposal methods, and other related information. The survey was not designed to provide estimates at State and county levels, but provides background information useful in helping address home/garden usage related to ground water concerns. EPA has conducted surveys of other urban/nonfarm sites in the past (e.g., golf courses and pest control operations). In the future, EPA will continue conducting annual surveys of certified applicators involved in nonagricultural pest control. The initial survey results, published in 1993, include estimates of pesticides used, rates, and use sites.

Homeowners and golf courses constitute significant categories of pesticide use. Suburban living styles commonly feature large grassy lawns highlighted by horticultural landscaping with shrubs and flowering plants. Maintaining such landscapes generally involves the use of fertilizers and pesticides. Residential structures are also major users of pesticides for termite control. Many of the problems associated with urban uses involve improper disposal of remnant quantities of pesticides or unintentional misuse. EPA's Office of Pesticide Programs conducted a national survey of home and garden use of pesticides in August and September, 1990. Information was collected on household use, storage, and disposal of pesticide products and containers.[5]

Some States require point-of-sale records on general pesticides largely to assemble overall estimates of pesticides likely used for homes and golf courses (Maine Board of Pesticides Control, 1990). Where restricted-use pesticides that require the services of custom applicators are involved, State applicator certification programs and other oversight measures provide indirect means of estimating the types of pesticides used in urban or suburban settings.

3.3 Geographic Information Systems

Geographic information systems (GIS) provide a computer-based method of storing, retrieving, analyzing, and displaying geographic and nongeographic data. A GIS is comprised of hardware and software that allows the use of data layering from a variety of existing sources. These sources include aerial photographs, topographic maps, land use and zoning maps, satellite images, and field notes. For example, a GIS can store the locations of specific pesticide application areas and vulnerable ground water sources and use this data to identify their geographic locations on a map.

[5] For further information and the conduct and results of this survey, contact the Office of Pesticide Programs, Biological and Economic Analysis Branch; Telephone: (703) 308-8050.

A number of State agencies have used GIS data bases to solve environmental management problems. For a majority of States, natural resource management and environmental planning have formed the primary applications for GIS technology (Warnecke, 1990).

- Two pilot projects are underway in Jefferson County, **West Virginia** and Lancaster County, **Pennsylvania**, to demonstrate the use of GIS in the development of SMPs. EPA's Region III and an interagency group of federal, State, and local agencies are cooperating to address environmental, agricultural, and health issues. The report on the Jefferson County project, titled "Use of GIS to Determine Ground Water Vulnerability to Contamination by Agricultural Chemicals: Jefferson County, West Virginia Pilot Study," is scheduled for completion by the Spring of 1994; the Lancaster County Pilot Study of Pequea and Mill Creek Watersheds is scheduled for completion in 1995. In both projects, farmers supplied data on pesticide usage and drinking water wells through EPA-sponsored interviews. USDA provided hydrogeologic information, including a water table elevation map and information on ground water flow; and the West Virginia Department of Natural Resources and Monsanto contributed a ground water vulnerability map. Spatial analyses include: evaluations of pesticide use with respect to the locations of permeable soils and vulnerable ground water, evaluations of at risk wells from: 1) pesticide applications; 2) point source contamination from pesticide handling, storage, and disposal techniques; and 3) comparisons of use information from various sources.

- The **Rhode Island** Department of Environmental Management and the University of Rhode Island have developed the Rhode Island Geographic Information System (RIGIS) to assist in the development of a ground water protection program (Baker et al., 1990). Applications include developing a State ground water classification system, delineating wellhead protection areas via the integration of RIGIS with ground water flow models, providing ground water information to local governments, and developing cartographic products.

- **Michigan** used GIS to produce a generalized map of aquifer vulnerability to surface contamination in Michigan. Using a 1980 version as a base map, soil permeability data (from USDA/SCS STATSGO) were overlaid on aquifer sensitivity information that was derived from well records.

- In **New York**, the Suffolk County Water Authority (SCWA) used GIS data bases to design a wellhead protection strategy to protect drinking water supplies from potential contamination caused by urbanization and over fertilization of agricultural lands (Scott, 1990). By integrating GIS with ground water flow and transport equations, SCWA developed a method of determining the zone of contribution (the area around the well that contributes water) for county wells. Three zones were delineated based on various hydrogeologic factors, including radius about the well, pumping rate, aquifer permeability and thickness, duration of pumping, and direction and velocity of ground water flow.

- In **California**, the San Joaquin Valley Drainage Program identifies and addresses problems associated with the drainage of agricultural lands in the San Joaquin Valley (Hansen, 1990). This program involves the coordination of programs managed by the both State and federal agencies. The objectives of the program are to maintain the agricultural productivity of the area, to restore the viability of the areas's fish and wildlife, and to identity areas of affected water quality and public health from drainage of agricultural land. The basic task of the program involves the establishment of a spatial data base containing all information held or developed by the program.

GIS can also perform data base management functions. Because data about a geographic area may change with time (e.g., pesticide use, agricultural practices, and water use), data layers may require frequent updating. GIS allows data already existing in the system to be updated (i.e., modified or deleted) as conditions change.

The remainder of this section discusses considerations for developing a GIS, how GIS can be used to develop and implement SMPs, and concludes with several examples of how several States implemented GIS, thus enhancing their water resource protection efforts.

3.3.1 Advantages for SMP Development and Implementation

GIS technology can be an integral part of a strategy to prevent, monitor, and respond to pesticide contamination in ground water. For example, a spatial data base that contains data on current and past pesticide use and vulnerable drinking water areas can be used by States to assess pesticide contamination risks and potential impacts on drinking water and display geographic areas at risk. States can incorporate GIS technology into their SMPs in several ways. These include:

- Identifying areas that are sensitive or vulnerable to pesticide contamination by overlaying data on hydrogeologic and pesticide-use characteristics (GIS technicians should not mix data that represents different map sources);

- Cataloguing drinking-water well locations, pesticide mixing, loading, and storage locations, pesticide detections and concentration levels, geographic distribution of agricultural practices, and pesticide use information;

- Integrating GIS technology with flow and transport models to predict time-dependent concentration distributions for geographic areas;

- Analyzing spatial and temporal changes in water quality;

- Generating what-if scenarios and analyzing impacts of changing management practices;

- Planning geographic areas included in response implementation measures; and

- Providing communication materials (e.g., maps) for public outreach.

3.3.2 Implementation Considerations

State agencies that are planning to implement GIS should consider the following factors:[6]

Cost. The cost of setting up a GIS system may range from $10,000 for a simple PC-based system to several hundred thousand dollars for a multi-user workstation system. The system cost will depend on the hardware and software required to support the GIS needs. A system may include input devices (e.g., terminal, scanners, digitizers), data storage (e.g., stand alone disk drives, tape drives), output devices (e.g., plotters, visual monitors), and a variety of software packages (e.g., data base management, statistical analysis, modelling, mapping). To reduce the costs of developing a GIS and thus avoid duplicating existing efforts, States should consider enhancing existing systems to support the implementation of their SMPs.

> A DRASTIC map of Nebraska, using commercially available GIS software, was completed in about one year by student employees at a cost of about $66,000. Data were collected for all 7 DRASTIC parameters for the whole State, digitized, and mapped to yield a complete State index map with a 1:1,000,000 scale. The project also prepared a comprehensive flow chart illustrating the process. (Rundquist, et al. 1991) Contact: Nebraska Department of Environmental Quality, Ground Water Section, Lincoln, Nebraska; Telephone: (402) 471-0096.

Data Availability and Data Integrity. Many organizations at federal, State, and local levels have GIS capabilities including data and information which, if shared, can save resources and time. Data on soil types, pesticide use, ground water, and weather, for example, are of interest to a number of programs, and exchange of such data is encouraged. The source of the data layers that are used to build the GIS data base may not be in a format that is recognized by the GIS technology. Consequently, additional time, hardware, and/or software may be required to translate the data into a suitable format. In addition, the quality of spatial analyses afforded by GIS is only as good as the quality of the data layers available for input into the system. Further, some data entry practices, such as entering data that are compiled at different scales, may limit the usefulness of the

[6] Under the Pollution Prevention Initiative, EPA's Office of Research and Development is developing guidance for States to use in selecting and implementing GIS. Information sources are provided in Chapter 7.

data. The costs associated purchasing and/or entering data may significantly increase the capital outlay for a GIS.

- **Functionality and Ease of Use.** The intended use of a GIS is an important criteria for selecting the hardware and software that will make up the system. Therefore, the specific functions that the GIS is to perform must be clearly identified prior to purchasing the GIS-related hardware or software. In addition, the ease of use of the system should also be considered. The complexity of the system and the availability of "easy-to-understand" user documentation will influence the amount of user training. If extensive training is required, the cost of the system could increase significantly (Sham, 1990).

- **Personnel.** The personnel functions necessary to support a GIS include data input (e.g., keyboard operators, scanner operators), data management (e.g., programmers, statistical analysts), data storage (e.g., computer operators), and data output (e.g., plotter operators). The level of experience and technical training required to develop a GIS will directly affect the cost of the system.

3.4 Defining Reasonably Expected Uses of Ground Water

The Final Comprehensive State Ground Water Protection Program Guidance (Final CSGWPP Guidance) describes an interactive process for defining reasonably expected uses of drinking water that will afford States greater attention to uses which have particular value or benefit through a differential management approach. These uses may include ecological support and drinking water, as well as other purposes. States may also want to consider other principal uses and factors, such as for agriculture and industry. It is left to the States to determine relative priorities among the uses. For SMPs, however, the protection of currently and reasonably expected sources of drinking water, both public and private, is a required priority.

The approach described below, as adopted from the Final CSGWPP Guidance, allows each State to tailor resource based priority-setting to its own institutions. First, a public process is described for defining the reasonably expected uses of ground water. Second, factors are identified for States to consider in defining ground waters reasonably expected to be used for ecological purposes and drinking water. Third, an EPA default definition for Federal program purposes will be applied to the extent needed to implement regulatory programs in States choosing not to define these uses. This approach is described below.

3.4.1 Public Process

To obtain the operational flexibility through the CSGWPP, the State's public process to determine reasonably expected uses should (a) maximize public input, and (b) have its results consistently applied across programs.

The State should utilize a public participation process with objectives as defined in 40 CFR Part 25. State laws designating ground water uses are considered adequate for this purpose. States are encouraged to keep their ground water use designations current. The objectives of 40 CFR Part 25 are to:

- Ensure that the public has the opportunity to understand official programs and proposed actions;
- Ensure that the government decision defining reasonably expected uses includes consulting interested and affected segments of the public;
- Ensure that the government action is as responsive as possible to public concerns;
- Encourage public involvement in implementing environmental laws;
- Keep the public informed about significant issues and proposed project or program changes as they arise;
- Foster a spirit of openness and mutual trust among EPA, States, sub-state agencies, and the public; and
- Use all feasible means to create opportunities for public participation and to stimulate and support participation.

- The State should consistently apply its definitions of ground water uses across all prevention and remediation decisions over which the State has control. For example, (i) the State should use a consistent definition regardless of waste type (e.g., sewage sludge or municipal solid waste) in determining facility requirements, and (ii) a State's definition would apply similarly to State and Federally funded remediation. As another example, application of a State's definition, which would require remediation programs to create an "island of clean" within a larger region of previously contaminated ground water, could be considered an inconsistent application.

3.4.2 Defining Reasonably Expected Uses for Ecological Support and Drinking Water

While States are expected to consider all uses, this section focuses on support of ecological systems and drinking water, because most laws that EPA implements focus on human health and the environment.

- **For Ground Water Supporting Surface Water Ecosystems:** EPA's 1991 Ground Water Protection Strategy emphasizes protection of ground water closely hydrologically connected to surface waters to ensure ecosystem integrity. EPA considers the following factors important indicators of ground water hydrologically connected to surface water. A State may choose to use other factors. States should negotiate with the EPA Regions which factors are most appropriate for their respective circumstances.

    - Relative ground water travel time from potential contaminant sources;
    - Relative contribution of ground water to quantity and quality (chemical and physical) of surface water;
    - Biota living in or dependent on ground water/surface water ecosystems;
    - Climatic or seasonal variations; and
    - Attainment of water quality standards to support designated use of surface water.

- **For A Reasonably Expected Source of Drinking Water:** EPA considers the following factors to be important in evaluating the future use of ground water. EPA expects States to consider or dismiss, with a sound rationale, from consideration these factors when determining a reasonably expected drinking water source. The State may also use other factors. States should negotiate with EPA Regions which factors are most relevant to their respective circumstances.

    - Hydrologic characteristics, including water quality and quantity;
    - Availability and cost of alternative water supplies;
    - Demographics, including future growth and population patterns;

- Remoteness from likely areas of residential or other development;
- Land use planning;
- Remediation technology for, and practicality of, remediation;
- Cost of prevention and remediation; and
- Inter-jurisdictional considerations (Tribes, federal government, other States).

3.4.3 EPA's Definition of "Reasonably Expected Uses of Ground Water"

In the absence of State definitions, EPA's definitions of "Ground Water Supporting Surface Water Ecosystems" and "A Reasonably Expected Source of Drinking Water" will apply.

- **Ground Water Supporting Surface Water Ecosystems:** EPA's definition for ground water closely hydrologically connected to surface water and supporting its ecosystems is ground water which, if its availability or quality are affected, would result in surface water not meeting the water quality standards required to support its designated use. (This definition reflects the current state of information on ground water - surface water interaction. This definition may change as more information becomes available.)

- **A Reasonably Expected Source of Drinking Water:** EPA's definition for a reasonably expected source of drinking water is ground water that is available in sufficient quantity for its intended use and contains fewer than 10,000 mg/l total dissolved solids. This definition derives from the Safe Drinking Water Act, Part C - Protection of Underground Sources of Drinking Water, Section 1421. EPA has developed this definition to be as protective as possible of future ground water uses; however, EPA recognizes that this definition may be more comprehensive than a State may wish to be.

3.5 References

Aller, L., T. Bennett, J.H. Lehr, R.J. Petty, and G. Hackett. 1987. DRASTIC: A Standardized System for Evaluating Ground Water Pollution Potential Using Hydrogeologic Settings. National Water Well Association. 455 pp. PB87-213914.

Baker, C.P., E.C. Panciera, and P.V. August 1990. "Groundwater Protection and the Rhode Island Geographic Information System." *Proceedings of the Tenth Annual ESRI User Conference.* V. 1.

Berg, Richard C., and John P. Kempton. 1987. Stack-unit Mapping of Geological Materials in Illinois to Depth of 15 Meters. Illinois State Geological Survey Circular 542.

Berg, Richard C., John P. Kempton, and Keros Cartwright. 1984. Potential for Contamination of Shallow Aquifers in Illinois, Illinois State Geological Survey Circular 532.

Carsel, R.F., L.A. Mulkey, M.N. Lorber, and L.B. Baskin. 1985. "The Pesticide Root Zone Model (PRZM): A Procedure for Evaluating Pesticide Leaching Threats to Ground Water." *Ecological Modeling* 30:40-69.

Chen, H.H., and A.D. Druliner. 1987. Nonpoint Source Agricultural Chemicals in Ground Water in Nebraska--Preliminary Results for Six Areas of the High Plains Aquifer. USGS Water-Resources Investigations Report 86-4338.

Cohen, D.B., C. Fisher, and M. Reid. 1986. "Ground Water Contamination by Toxic Substances: A California Assessment." In Evaluation of Pesticides in Ground Water. American Chemical Society, Washington, D.C.

Congress of the United States, OTA (Office of Technology Assessment). 1990. Beneath the Bottom Line: Agricultural Approaches to Reduce Agrichemical Contamination of Groundwater. Washington, D.C: Government Printing Office. NTIS PB91-129874.

Enfield, G.G., R.F. Carsel, S.Z. Cohen, T. and D.M. Waiters. 1982. "PESTANS I and II." *Ground Water* 20:711-722.

Geraghty & Miller, Inc., and ICF Incorporated. 1990. A Review of Methods for Assessing the Sensitivity of Aquifers to Pesticide Contamination. Prepared for EPA's Office of Ground Water Protection under Contract No. 68-C8-0003 with accompanying workbook for the Boulder, CO, Workshop (July 24-25, 1990).

Gianessi, L.P. 1986. A National Pesticide Usage Data Base. National Center for Food and Agricultural Policy, Inc., Washington, D.C.

Gianessi, L.P., and C.A. Puffer. 1988. Use of Selected Pesticides in Agricultural Crop Production by State. National Center for Food and Agricultural Policy.

Gianessi, L.P., and C.A. Puffer. November 9, 1990. The Use of Herbicides in the United States. National Center for Food and Agricultural Policy. Presented at the National Research Conference, "Pesticides in the Next Decade: The Challenges Ahead," sponsored by Virginia Water Resources Research Center, Richmond, VA.

Gianessi, L.P., and C.A. Puffer. January 1991. Estimation of County Pesticide Use on Golf Courses and by Urban Applicators. National Center for Food and Agricultural Policy. PB89-191100.

Goss, D. 1988. Soil-Pesticide Interaction Ratings (SPIR) System. U.S. Department of Agriculture Soil Conservation System (addendum provided at Boulder Workshop).

Green, R.E., C.C.K. Liu, and N. Tamnaker. 1986. "Modeling Pesticides Movement in the Unsaturated Zone of Hawaiian Soils Under Agricultural Use." In: Evaluation of Pesticides in Ground Water. American Chemical Society. pp. 366-383.

Gustafson, D.I. 1989. "Ground Water Ubiquity Score: A Sample Method for Assessing Pesticide Leachability." *Environmental Toxicology and Chemistry* 8:339-357.

Hansen, D.T. 1990. "Description of the Data Directory of the San Joaquin Valley Drainage Program." *Proceedings of the Tenth Annual ESRI User Conference,* V. 2.

Khan, M.A., and T. Liang. 1989. "Mapping Pesticide Contamination Potential." *Environmental Management* 13:233-242.

Kissel, D.E., O.W. Bidwell, and J.F. Kientz. 1982. Leaching Classes of Kansas Soils. Kansas State University, Kansas Agricultural Experiment Station, Manhattan, KS. Bulletin 641. 10 pp.

Knisel, W.G., Ed. 1980. CREAMS: A Field-Scale Model for Chemical, Runoff, and Erosion from Agricultural Management Systems. USDA, Science Education Administration. Conservabon Report No. 26.

Lo, T.H. C., S.E. Dicks, and R. Christianson. 1990. "Identification of Natural Resource Lands for Acquisition within the Context of ARC/INFO GIS Framework." *Proceedings of the Tenth Annual ESRI User Conference*, V. 2.

Maine Board of Pesticides Control. November, 1990. Draft Pesticides in Ground Water Management Plan.

Moore, J.S. 1988. SEEPAGE: A System for Early Evaluation of the Pollution Potential of Agricultural Ground Water Environments. USDA, Soil Conservation Service, Chester, PA. 1 p.

Moreau, D.H. and L.E. Danielson. 1990. Agricultural Pesticides and Groundwater in North Carolina: Identification of the Most Vulnerable Areas. Water Resources Institute of the North Carolina State University, Raleigh. Report No. 252. NTIS PB90-235359.

Nofziger, D.L, and A.G. Hornsby. 1985. Chemical Movement in Layered Soil: User's Guide. University of Florida, Gainesville.

Pacenka, S. 1984. Diagnosing the Causes of Ground Water Contamination Using a Mathematical Model: Report on Technology Transfer Workshop. U.S. Geological Survey, Water Resources Division, Reston, VA. USGS/G-859(23). NTIS PB85-217008. 42 pp.

Piat, A.S., D.R.G. Farrow, J.A. Lowe, and P.A. Pacheco. 1989. Agricultural Pesticide Use in Estuarine Drainage Areas: A Preliminary Summary for Selected Pesticides. NOAA, Strategic Assessment Branch, National Coastal Pollution Discharge Inventory Program, Rockville, MD.

Rundquist, Rodekohr et al. 1991. "Statewide Groundwater Vulnerability Assessment in Nebraska Using the DRASTIC/GIS Model." *Geocanto International* 6(2):51-58.

Sacha, L., D. Fleming, and H. Wysocki. 1987. Survey of Pesticides Used in Selected Areas Having Vulnerable Ground Waters in Washington State. U.S. EPA, Seattle, WA. EPA 910/9-87/169. NTIS PB88-199674. 324 pp.

Scott, A.J. 1990. "Using a GIS for Analytical Modeling of Wellhead Protection Areas Around Public Water Supply Wells." *Proceedings of the Tenth Annual ESRI User Conference*. V. 1.

Sham, C.H. 1990. "Comments on Selecting a Geographic Information System for Environmental Management." *Environmental Management* 14:3.

Steichen, J., J. Koelliker, D. Grosh, A. Heiman, R. Yearout, and V. Robbins. 1988. "Contamination of Farmstead Wells by Pesticides, Volatile Organics, and Inorganic Chemicals in Kansas." *Ground Water Monitoring Review* 8:153-160.

Teso, R.R., T. Younglove, M.R. Peterson, D.L. Sheeks, and R.E. Gallavan. 1988. "Soil Taxonomy and Surveys: Classification of Areal Sensitivity to Pesticide Contamination of Ground Water." *Journal of Soil and Water Conservation* 43:348-352.

USDA Water Quality Initiative Team. 1990. Bibliography: Cooperative Extension System's Water Quality Educational Materials. USDA, Cooperative Extension Service.

U.S. EPA. 1987. "Pesticides and the Consumer." *EPA Journal* 13(4).

U.S. EPA. 1991. A Review of Methods for Assessing Nonpoint Source Contaminated Ground Water Discharge to Surface Water.

U.S. EPA. 1991. Pesticides in Ground Water Data Base: 1991 Draft Report. OPTS.

U.S. EPA. 1993. A Review of Methods for Assessing Aquifer Sensitivity and Ground Water Vulnerability to Pesticide Contamination. EPA 813-R-93-002.

U.S. EPA. 1992. Handbook for State Ground Water Managers: Using EPA Ground Water-Related Grants to Support the Development and Implementation of Comprehensive State Ground Water Protection Programs. EPA 813-B-92-001.

Wagenet, R.J., and J.L. Hutson. 1986. "Predicting the Fate of Nonvolatile Pesticides in the Unsaturated Zone." *Journal of Environmental Quality* 15:315-322.

Warnecke, L. 1990. "GIS in the States: Applications Abound." *GIS World* 3:3.

Wisconsin Department of Natural Resources and the Wisconsin Geological and Natural History Survey. 1987. Ground Water Contamination Susceptibility in Wisconsin.

Chapter 4

Prevention Components of SMPs

EPA's Pesticides and Ground Water Strategy emphasizes reducing unreasonable risks of pesticide contamination of ground water by managing pesticide use in a way that reduces or eliminates the leaching of pesticides to ground water in vulnerable areas. SMPs must identify general management measures designed to prevent ground water contamination associated with the use of registered pesticides in accordance with EPA-approved labelling. The prevention components of SMPs should include measures that will reduce or eliminate the risk of direct contamination of ground water, the risk of pesticides leaching into ground water in vulnerable areas, and the risk of ground water contamination resulting from normal agricultural practices. A State should tailor its preventive measures according to the State's farm practices and pesticides use; the State's unique hydrogeologic circumstances; the use, value and vulnerability of the State's ground water resource; and the State's regulatory structure for pesticide and water quality management. Each State has a unique set of circumstances in which to determine the appropriate preventive measures. In determining measures, States will need to convene those individuals from State agencies, USGS, and USDA (e.g., Soil Conservation Service, Extension Service) who have experience and knowledge about the specific State conditions.

A State must develop and implement measures to prevent ground water contamination from pesticides. When a specific pesticide is found in ground water, the preventive measures must be applicable to the pesticide and the target crop the pesticide is applied to. The Guidance for Pesticides and Ground Water State Management Plans provides that both a State's Generic SMP and a Pesticide SMP should:

- Address the types of preventive measures that will be implemented in the absence of actual detection of pesticides in ground water which the State has deemed to be valuable or vulnerable. Indicate how prevention measures will be reevaluated and what increasingly stringent types of measures will be imposed if contamination of ground water is found or is increasing toward the reference point. The SMP must also indicate the factors and rationale considered in choosing these measures and the triggers that would lead to a State's implementation of more stringent measures. At a minimum, confirmed detections of a pesticide in ground water need to be treated as a cause for concern and should trigger some action to diagnose the cause of the particular detection and determine whether any further regulatory/management approaches are needed. For example, a State may indicate that it will implement educational efforts regarding source reduction of pesticides, even when the pesticide has not been detected in ground water; that if detections are confirmed in ground water the State will move to measures that involve enforceable use limitations; and that if the level of a pesticide or breakdown product in ground water is found to be increasing toward the MCL or other established reference point, the State will implement use prohibitions.

In addition to the Generic Plan Criteria listed above, a Pesticide Plan must:

- Identify specific preventive approaches (i.e., specific application rates, specific tilling practices or other best management practices, use restrictions and prohibitions, etc.) that will be employed on a voluntary or required basis. Pesticide SMPs should be self adjusting and include a range of contingency plans that would be triggered by pesticide detections found in ground water, or new information on the level of risk posed by the contamination, pesticide usage patterns, as well as ground water vulnerability, use and value.

- Explain the rationale for the specific prevention measures chosen and indicate the feasibility of implementing those measures. For example, the plan could briefly document how the specific prevention measures have been used successfully in the State or, for new measures, the results of research or demonstration trials where the measures have been shown to be effective.

- Describe at what levels of detection (from zero to the reference point) the State will implement certain prevention or response measures. (See EPA's Policy on Use of Quality Standards, page 3-15 of Guidance for Pesticides and Ground Water State Management Plans.)

  In establishing preventive steps and response actions the State should consider, among other factors, the level of contamination compared to the MCL or other established reference point. Where a pesticide has or is considered likely to reach reference points (reaching the reference point marks the point of failure of the ground water protection goal), the most stringent actions should be taken to stop further contamination. These actions can range from enforcement actions to modification of the way a pesticide is managed, including geographically-defined prohibitions or moratoria on the pesticide's use. (See Component 8.)

- Address potential adverse impacts of the specific measures employed by a State to surface water in addition to ground water. For example, the plan would address whether a change in a tillage practice instituted to reduce ground water contamination infiltration may in some instances increase surface water runoff. In addition, if a State expects that a risk reduction measure will lead users to use alternative chemicals, then EPA encourages the State to consider whether the alternative chemicals will cause adverse effects for ground water, surface water or other areas. (EPA rulemaking will have analyzed the most likely alternative chemicals including their risks and benefits.)

EPA also strongly encourages States to implement measures to protect surface water from pesticide contamination that is likely to impair water quality.

The preventive measures a State chooses to implement may vary based on ground water use value, and vulnerability, pesticides use, and social and economic factors. The measures may range from education efforts to use limitations or prohibitions in certain areas. Particular emphasis is placed on the protection of sensitive aquifers. The stringency of preventive measures may vary, however, from State to State and even within a State as a reflection of differences in pesticide usage and/or aquifer sensitivity. EPA encourages States to adopt best management practices (BMPs), integrated pest and crop management (IPM/ICM) practices, sustainable agriculture, and other approaches that result in reduced risk of ground water contamination, even in the absence of concern regarding a specific pesticide. SMPs should provide a range of prevention alternatives implemented both prior to and after a chemical's detection in ground water. Provisions for evaluating the success of preventive measures should be an integral part of a prevention plan.

EPA recognizes that a number of existing State programs implement ground water protection and preventive measures. Table 2-1 (Chapter 2) summarizes some existing EPA programs which address ground water protection and nonpoint source contamination. As described in Chapter 7, other federal agencies also administer programs which parallel and support some components of SMPs (e.g., nonpoint source programs authorized under the Coastal Zone Management Act). Whenever possible, a State should coordinate common preventive measures with those developed for SMPs to minimize duplication of effort.

This chapter focuses on the development of State plans to prevent ground water contamination by pesticides. The measures presented in this chapter are suggestions that should be evaluated and implemented as appropriate given the specific goals and conditions in each State and the guidelines presented in Appendix A. Examples are provided to encourage States that do not have specific management measures in place to seek information from other States and to subsequently develop prevention strategies appropriate to their State. This Chapter includes:

- A description of how the prevention, monitoring, and response components of SMPs are related;
- An overview of management measures that protect ground water from contamination;

- A framework for tailoring prevention plans to State-specific needs and conditions; and

- A discussion of the State's implementation considerations.

4.1 Interrelatedness of the Prevention, Monitoring, and Response Components

Preventive measures begin to overlap with monitoring and response measures at the point that pesticide contamination of ground water is found. A response to a detection may include instituting additional or different, more stringent, preventive measures. EPA encourages States to adopt preventive measures before contamination is found to reduce the risk that pesticides will reach ground water. The stringency of preventive measures to protect ground water should increase with an aquifer's sensitivity or as concentrations of detected pesticides approach reference points. Figure 4-1 depicts the potential relationship between these prevention, monitoring, and response components and the integral part that ground water monitoring plays in devising prevention strategies.

The SMP approach incorporates EPA's policy of using reference points to determine the level of stringency for ground water protection activities. Reference points should be applied differently for prevention and response purposes. For prevention activities, detection of a pesticide at a percentage of the reference point triggers additional prevention actions, such as limiting the use of the pesticide. In general, detection of a pesticide at or above the reference point initiates the State's response to stop further contamination (e.g., banning the use of the pesticide in the area). It is important to recognize that the use of reference points is not a "license to pollute." Rather, reference points serve as means to define failure of preventive measures and to generally identify the need for the most stringent measures to protect ground water from further pesticide contamination. In specific instances, considerations such as ground water use, value, vulnerability, and social and economic values may play a part in determining appropriate response measures.

4.2 Measures that Protect Ground Water from Pesticide Contamination

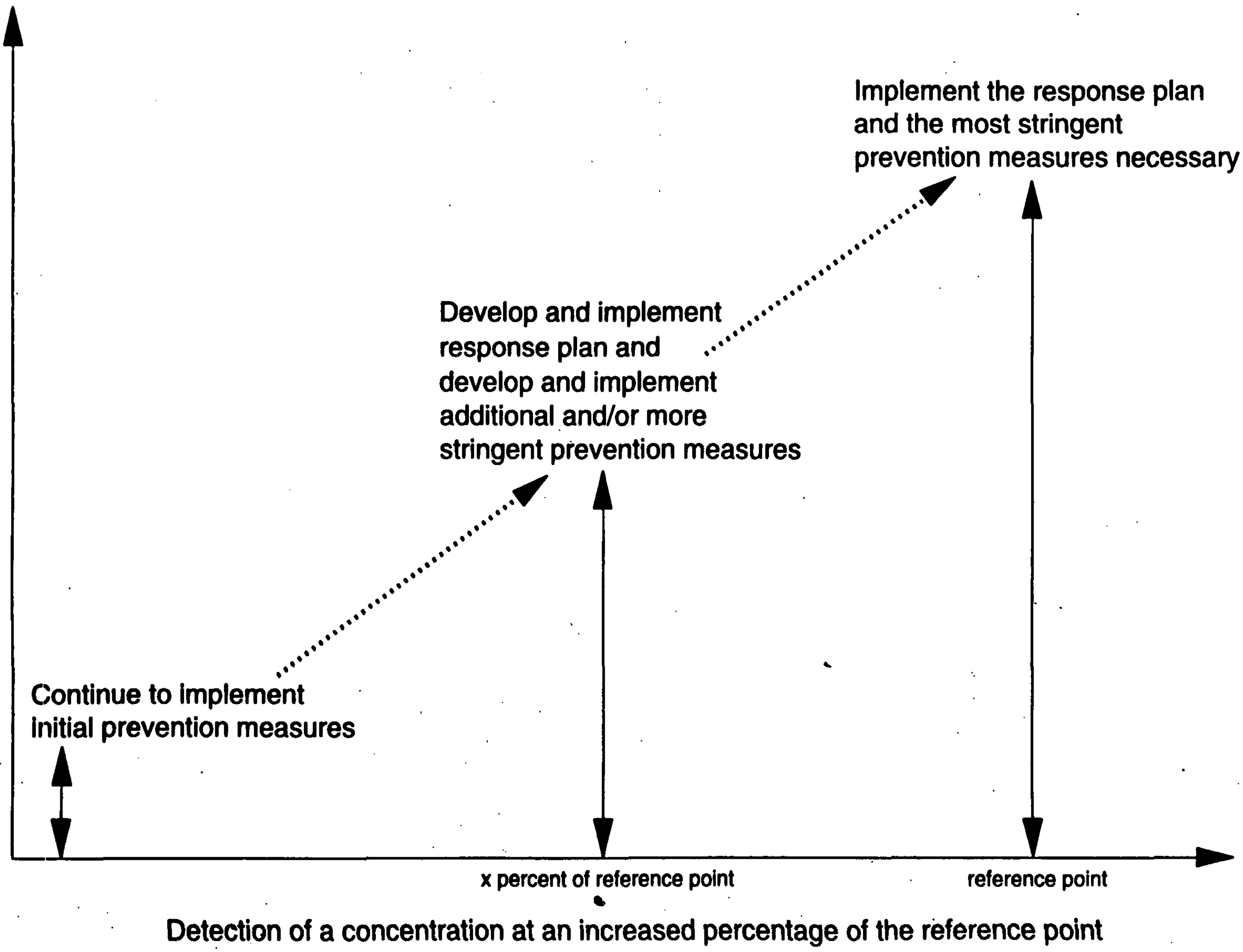
In developing the prevention component of both Generic SMPs and Pesticide SMPs, States should consider the following four main approaches to ground water protection:

- Measures that control sources of direct pesticide contamination of ground water;

- Measures that limit the use of pesticides;

EXHIBIT 4-1

RELATIONSHIP AMONG PREVENTION, MONITORING, AND RESPONSE



- Measures that reduce the potential for pesticide leaching to ground water; and

- Measures that reduce the quantity, toxicity, or persistence of pesticides used.

Descriptions and examples of each category of preventive measures are presented in the following sections. The discussions address a range of options for increasingly stringent implementation of each preventive measure.

4.2.1 Measures that Control Sources of Direct Pesticide Contamination of Ground Water

Although pesticides have numerous beneficial uses, pesticides also pose a risk of direct contamination of ground water. Studies in a number of States suggest that high pesticide concentrations in ground water may be attributed to improper handling, loading, storage or disposal of pesticides (U.S EPA, 1988). Therefore, proper handling, storage, and disposal of pesticides and proper well construction and abandonment practices may minimize the potential for pesticides to enter ground water directly. State SMPs should address how to identify potential point sources of contamination (e.g., locations of pesticide storage and distribution centers). In addition, SMPs should address how appropriate pesticide handling practices and proper well construction and abandonment practices that minimize the potential for direct transport of pesticides to the water table will be achieved.

Pesticide Handling, Storage, and Disposal

Improper handling, storage, or disposal of pesticides may result in the release of these materials into ground water at concentrations that greatly exceed those of routine application. The FIFRA 88 amendments expanded EPA's authority to regulate storage, transportation, and disposal of pesticides beyond the rules currently found in 40 CFR Part 165. EPA has conducted studies of pesticide container design and may take additional regulatory action in the future (see 56 Federal Register 54025, October 21, 1991).

The State of Wisconsin identified numerous sites where pesticide handling, storage, or disposal resulted in ground water contamination. As a result, the Wisconsin Department of Agriculture, Trade, and Consumer Protection developed administrative rules and guidance covering proper pesticide handling and storage; secondary containment requirements for mixing, loading, and storage areas; response plans for environmental discharges; and detailed recordkeeping. For further information on pesticide handling practices in Wisconsin, contact the Wisconsin Department of Agriculture, Trade, and Consumer Protection, 801 West Badger Road, Post Office Box 8911, Madison, Wisconsin 54708-8911; Telephone: (608) 266-2295.

As the example from Wisconsin indicates, States can also implement prevention programs that minimize the risk posed by improper handling, storage, or disposal of pesticides in either a Generic or a Pesticide SMP.

In managing pesticide use to prevent direct contamination from pesticides, a State should recognize the importance of:

- Location factors;
- Spill or leak factors;
- Application factors; and
- Pollution prevention factors.

Consideration of each factor influences the implementation of selected pesticide management practices. Table 4-1 presents a variety of pesticide management practices recommended to protect ground water resources from pesticides contamination. The table demonstrates how management practices can be applied to specific pesticide use activities (e.g., mixing, loading, rinsing, storage, and disposal).

The **Minnesota** Department of Agriculture has addressed the proper disposal of waste pesticide materials via rinse and load setbacks. As a component of voluntary BMPs for Atrazine, the Minnesota Department of Agriculture has proposed rinse and load setbacks from wells, sinkholes, or surface water of 150 feet (Minnesota Department of Agriculture, 1990b). In addition, the State conducted a pilot project on container collection and recycling to promote county-based pesticide container programs. For further information on pesticide disposal practices in Minnesota, contact the Minnesota Department of Agriculture, 90 West Plato Boulevard, St. Paul, Minnesota 55107; Telephone: (612) 297-7264.

The preparation and application of pesticides provides numerous opportunities for spills, accidents, and leaks. Improperly disposed pesticide wastes provide concentrated point sources of contamination that could adversely affect ground water quality. A State should address improper pesticide use or application through certification and training

Table 4-1. Examples of Pesticide Management Practices for Ground Water Protection

Pesticide Management Practices	Pesticide Use Activities				
	Mixing	Loading	Rinsing	Storage	Disposal
Location Factors:					
Away from wells	✓	✓	✓	✓	✓
Away from sinkholes/other conduits to ground water	✓	✓	✓	✓	✓
On impervious pads or foundations	✓	✓	✓	✓	
Spill or Leak Factors:					
Care in handling containers	✓	✓			
Covered storage areas				✓	
Spill containment measures (dikes or berms)	✓	✓	✓	✓	
Routine inspection of facilities	✓	✓	✓	✓	✓
Inventory of materials				✓	✓
Emergency response planning for releases	✓	✓	✓	✓	
Availability of Material Safety Data Sheets (MSDS)			✓	✓	✓
Application Factors:					
Use of closed systems	✓	✓	✓		
Use of anti-backsiphoning techniques	✓				
Maintenance of application equipment	✓	✓			
Calibration of application equipment	✓	✓			
Use of certified applicators	✓	✓	✓	✓	✓
Pollution Prevention/Waste Minimization Factors:					
Following label instructions	✓	✓	✓		✓
Reduction of leftover tank mixes	✓				
Spraying of rinse water on cultivated fields			✓		
Inventory Control				✓	✓

programs and continuing education programs for pesticide applicators. Proper storage and disposal of pesticides can also be addressed through technical assistance and public outreach.

A State may institute increasingly stringent preventive measures for pesticides handling, storage, and disposal depending on the risk posed by a specific pesticide. For example, karst or other hydrogeologically sensitive areas may require special preventive measures, because accidental spills or leaks in these areas may be transmitted directly and quickly to ground water. However, EPA encourages States to implement prevention management practices for pesticides handling, storage, and disposal throughout the State to ensure that the risk posed by direct contamination of ground water is significantly reduced.

Proper Well Construction and Abandonment

Improper seals on active or abandoned wells provide direct pathways for pesticides and agricultural runoff to reach ground water and impact drinking water supplies. Proper construction of wells minimizes the potential for direct transmission of pesticides along the borehole to the ground water. A State well water program addresses these potential sources of contamination through practices such as:

- Well construction standards, including well casings, seals, and surface completions;
- Requiring well drillers or well owners to file completion reports for new domestic wells;
- Regulating underground injections;
- Certification and ongoing education programs for well drillers, pump installers, and test samplers;
- Inspections of wells and enforcement of well construction standards and abandonment standards; and
- Public education and outreach programs for private well users.

In addition to new wells, States should consider applying these standards to older wells, irrigation wells, or agricultural drainage wells. Poor construction or maintenance of these conduits can transport pesticide-laden field runoff to ground water.

In addition, poorly sealed abandoned wells may transmit runoff from agricultural fields to ground water. Simple backfilling of abandoned wells may not be sufficient to prevent the vertical movement of water from the land surface to ground water. A State should consider the development and implementation of proper well abandonment procedures, including:

- Removing the well casing;
- Filling the borehole with grout or other low-permeability materials; and
- Placing a concrete cap over the plugged hole.

Although many States maintain standards and guidance on the proper abandonment of wells and subsurface conduits, such standards are often difficult to enforce (Aller et al., 1990). Therefore, a State should consider developing inspection and enforcement programs to ensure properly abandoned wells. As an alternative some States require the reporting of well abandonment procedures and materials (Wisconsin Department of Natural Resources, 1985).

A State may take the preventive measures described above separately or in combination with other measures. A State may institute increasingly stringent preventive measures relating to well construction, use, and abandonment depending on the risk posed by a specific pesticide to wells within a State. For example, a State may choose to conduct inspections of private wells in hydrogeologically sensitive areas. However, EPA encourages States to implement preventive measures for well construction, use, and abandonment throughout the State to ensure that the risk posed by direct contamination of ground water is significantly reduced.

4.2.2 Use Limitations or Prohibitions

Limitations on pesticide use can be an effective tool to protect against pesticide contamination of ground water. Use limitations can apply both to application techniques and/or to geographic settings. In addition, limitations could become increasingly stringent if pesticides are found in ground water, or are moving toward the reference point.

Pesticides Application Limitations

Measures that encourage farmers to select pesticide application methods that discourage leaching to ground water may reduce the risk of ground water contamination. Such preventive measures range from voluntary practices to label requirements on pesticides. Preventive measures associated with pesticide application limitations include:

- Requiring comprehensive education and training for pesticide applicators;
- Requiring proper calibration and maintenance of application equipment;

- Limiting the timing and frequency of pesticide applications to coincide with periods of lower infiltration; and

- Limiting aerial and ground-based application of pesticides.

Applicator Education and Training. Under FIFRA, all States must have a satisfactory certification program administered either by EPA or a State agency for pesticide applicators so they can legally use restricted-use pesticides. EPA classifies a pesticide in the restricted-use category if the pesticide may cause unreasonable adverse effects to the environment or injury to the applicator. EPA's Office of Pesticide Programs, Certification and Training (C&T) program assists State FIFRA agencies, State land grant universities, and the USDA Cooperative Extension Service in offering training programs to certify commercial and private pesticide applicators. Recently, the President's Water Quality Initiative strengthened the USDA's involvement in the C&T program.

In either a Generic or a Pesticide SMP, a State may describe its plans to enhance applicator training and testing requirements for specific pesticides that pose a significant threat to human health and the environment through ground water contamination. Such requirements would better inform pesticide applicators of the risk of pesticide contamination to ground water and how to minimize that risk.

Wisconsin's Atrazine Rule for 1991 requires a reduced application rate of one pound per acre per year for coarse soils and 1.5 pounds for medium and fine soils if atrazine was used the previous year. If atrazine was not used the previous year, the rule requires a reduced application rate of 1.5 pounds per acre per year for coarse soils and two pounds per acre per year for medium and fine soils. For the lower Wisconsin River Valley, atrazine use is limited to 0.75 pounds per acre per year on sand or loamy sand. In all areas of Wisconsin, atrazine use is restricted to certified applicators, application is prohibited before April 15 or after July 31, and cannot be applied through irrigation systems. In addition, irrigation is prohibited on any field for two years after atrazine application unless an irrigation scheduling program is used. Applicators must complete a record of use on the day of application for each field treated. These records must be kept for three years. For more information on Wisconsin's Atrazine Rule, contact the Wisconsin Department of Agriculture, Trade, and Consumer Protection, Agricultural Resource Management Division; Telephone: (608) 266-2295.

Requirements for Calibration and Maintenance of Application Equipment. Proper maintenance and calibration of pesticide application equipment is critical to ensure even application of pesticides and accurate application rates. Poorly maintained or calibrated equipment results in excessive discharges of concentrated pesticides and the subsequent leaching of pesticides to ground water. Pesticide application equipment should be maintained and calibrated periodically to ensure accurate pesticide delivery volumes. Properly maintained automatic volume-regulating devices, which function by varying spray pressure according to the speed of the application equipment, are helpful in maintaining appropriate pesticide application rates.

Through an SMP, a State can limit pesticide application to specific equipment or calibrations. In addition, a State may require the testing and inspection of pesticides application equipment to ensure proper maintenance and calibration. Such requirements ensure the proper maintenance and calibration of application equipment to reduce the risk of pesticide contamination of ground water.

Limitations on Application Timing, Rate, and Frequency. The timing, rate, and frequency of pesticides application is an additional factor in its potential to leach into ground water. Applying pesticides during a period of lower infiltration, or reducing the rate of application pesticide applicators may enhance the safe and effective utilization of pesticides.

Through an SMP, a State may choose to limit pesticide application to certain periods during the year and with prescribed frequency. Such restrictions on the time and frequency of pesticide application can significantly reduce the risk of pesticide contamination of ground water.

Limitations on Aerial and Ground-Based Application. Aerial application of agricultural pesticides is accomplished by spraying pesticides from airplanes or helicopters. Uniform application to foliar surfaces may vary due to wind conditions during application periods. Consideration of wind patterns and weather conditions is necessary to ensure uniform application rates and to minimize the likelihood that pesticide concentrations will impact surface waters.

California, Arizona, and Hawaii have statutory authorities which requires reporting of environmental fate data relating to ground water pollution for agricultural pesticides. These States also have regulatory authorities to impose use limitations or prohibitions, require monitoring, and require special applicator training to reduce the contamination risk in vulnerable areas.

Pesticides may be applied to foliar surfaces, the ground surface, or incorporated into soil using a number of ground-based application methods. In general, soil application methods pose a greater potential for leaching to ground water than do foliar application methods.

Through an SMP, a State may limit aerial or ground-based application of pesticides to certain time periods or geographic areas. Such limitations could be increasingly stringent based on the pesticide's potential for leaching to ground water. Restrictions on pesticide application methods can significantly reduce the risk of pesticide contamination of ground water.

Geographic Settings Limitations

Limiting the use of pesticides in the area around water supply wells, well recharge areas, or other sensitive hydrogeologic settings may reduce the risks from pesticide contamination of ground water resources. Two approaches to utilizing geographic settings are:

- Establishing more stringent preventive measures for more sensitive hydrogeologic settings; or

- Limiting or prohibiting the use of pesticides in sensitive hydrogeologic settings.

Specific preventive measures or limitations can be stipulated in the SMP or as label requirements on pesticides. The most stringent and most protective preventive measure is a moratorium on pesticide use in a particular area of the State that is susceptible to ground water contamination.

Through assessments of aquifer sensitivity and ground water vulnerability efforts, a State can tailor the preventive measures of its Generic and Pesticides SMPs to its unique hydrogeologic settings. A State should consider the following types of geographic settings or areas for potential pesticides use limitation or implementation of other more stringent preventive measures:

- Wellhead protection areas for public water supply wells;

- Wellhead protection areas for private water supply wells;

- Sole Source Aquifers; and

- Other areas identified in the State's ground water resource assessment and characterization.

Wellhead Protection Programs for Public Water Supply Programs. Wellhead protection areas are used to prevent the contamination of ground water used as a public water supply. The concept of protecting ground water supplies in the vicinity of public drinking water wells is central to the Wellhead Protection Program, authorized by the 1986 amendments to the Safe Drinking Water Act. EPA has approved 31 State Wellhead Protection Program plans and several more are currently under review. A number of local wellhead protection efforts also exist.

Guidance on the establishment and management of buffer zones, or Wellhead Protection Areas (WHPAs), is available from EPA's Office of Ground Water and Drinking Water (U.S. EPA, 1987). State Wellhead Protection Programs provide technical assistance and other support to local communities interested in protecting wellhead areas

EPA Region I, the Connecticut Department of Environmental Protection (DEP), and the USDA Soil Conservation Service (Connecticut State Office) conducted a pilot study in the town of Cheshire. As part of this effort, a variety of local ordinances, bylaws, and inspection programs were developed. The work completed under this study was used in developing The Manual of Best Management Practices for Agriculture: Guidelines for Protecting Connecticut's Water Resources.

Another approach to wellhead protection is the **Massachusetts** Aquifer Lands Acquisition Program. This program enables the Massachusetts Department of Environmental Quality Engineering to reimburse communities which purchase the land or easements necessary to secure buffer areas around wellfields. Currently, Massachusetts implements half-mile protection zones around community wellhead areas. Adjustments will be made as more precise recharge areas are calculated.

or aquifer recharge areas. State authorities should coordinate Wellhead Protection Programs and SMPs.

Wellhead Protection Areas for Private Water Supply Wells. Some existing State ground water protection efforts focus on protection of areas around private water supply wells, which supply drinking water to families on farmsteads and other rural residences. Local efforts and resulting resident actions may in effect result in a wellhead protection plan for private wells.

The Farmstead Assessment System (Farm-*A*-Syst) could serve as the foundation for the creation of a more comprehensive private wellhead protection plan. Farm-*A*-Syst was developed in response to farmers' concerns about protecting water quality, and because farmsteads (i.e., the farm buildings and the land around them) can be a major source of rural water contamination. Farm-*A*-Syst uses ten easy, step-by-step worksheets that rank farmstead activities and structures (such as pesticide handling sites and livestock waste storage areas) that could cause groundwater contamination. A separate worksheet assesses how soil, geologic, and hydrologic features of the farmstead affect the ground water pollution potential at that site. An overall evaluation worksheet is then used to summarize voluntary actions that can be taken to protect drinking water. Information on available financial, technical, and education assistance is also provided in companion brochures.

Farm-*A*-Syst was initially developed as a cooperative project of EPA's Region V Office and the Wisconsin and Minnesota Extension Services (ES). It is currently a national effort supported by EPA, ES, and the Soil Conservation Service (SCS). A national staff provides support to States interested in adapting the Wisconsin and Minnesota prototype Farm-*A*-Syst program for their particular agricultural, programmatic, and regulatory circumstances. As these modified State assessments are available across the country, they become valuable tools for facilitating actions by farmers and rural residents to reduce drinking water contamination risks from pesticides and other farmstead sources.

All pesticide management practices in Table 4-1 are addressed in the prototype Farm-*A*-Syst. Proper well construction and management, noted in this guidance, is also facilitated by use of Farm-*A*-Syst. Other potential sources addressed by the system are fertilizer and petroleum product storage and handling, household and farmstead hazardous waste management, household wastewater management, livestock waste and yards management, silage storage, and milking center wastewater management.

Sole Source Aquifer Program. Under the Safe Drinking Water Act, EPA designates aquifers as a sole or principle source of drinking water in order to maintain or improve underground drinking water quality. Designation requires EPA review of federal financially-assisted projects to ensure that ground water is being protected.

A Sole Source Aquifer Protection Plan includes a map showing the detailed boundary of the critical protection area. Guidance on the establishment and management of Sole Source Aquifer Areas is available from EPA's Office of Ground Water and Drinking Water. A State's SMP should give special consideration to delineations of existing sole source aquifer designations.

Ground Water Resource Assessment and Characterization. The Guidance for Pesticides and Ground Water State Management Plans requires a State to describe in its SMP the methods by which it identifies and differentiates the use, value, and vulnerability of its ground water. One of the primary purposes of the assessment is to determine the hydrogeologic settings most susceptible to pesticide leaching to ground water.

Once the assessment is completed, the State should develop appropriate prevention and use limitations or prohibition measures. In areas with high aquifer sensitivity and high ground water value and vulnerability, States should consider more stringent preventive measures. In some settings where aquifer sensitivity and ground water vulnerability are particularly high, a State may choose to ban the use of pesticides completely or to prohibit the use of pesticides with high leaching potential.

4.2.3 Reduction of Leaching Potential

The selection of pesticides and application methods that reduce leaching to ground water may lower the risk of ground water contamination. Both Generic and Pesticide SMPs should discuss how States will encourage practices such as using pesticides with low leaching potential, varying application and irrigation methods according to ground water susceptibility, and timing carefully pesticide applications. In general, management of pesticides as nonpoint sources for ground water contamination should be addressed in SMPs. (See USDA 1991 for a bibliography of recent materials on issues and techniques for managing nonpoint sources.)

Selecting Pesticides with Low Leaching Potential

In general, the leaching potential of a pesticide is related to the pesticide's formulation, persistence, solubility, and sorption characteristics (U.S. EPA, 1988).

Therefore, the selection of pesticides with chemical traits that have low leaching potential characteristics and are effective at pest control may provide the most successful ground water protection option. Information on pesticides collected from pesticide leaching methods (described in Chapter 3) may be useful in identifying pesticides with low leaching potential for specific applications.

A pesticide's formulation can affect its leaching potential by, for example, delaying or preventing the pesticide from reaching the soil surface. Formulations that use hydrocarbon solvents or "stickers" may reduce the amount of pesticide that enters the soil by promoting increased adherence of the pesticide to plant surfaces and reducing "wash-off" of the pesticide by rains or irrigation. Alternatively, granules and encapsulations may reduce leaching by controlling the release of pesticides to the environment. Other formulations such as wettable powders, soluble powders, liquids, aqueous concentrates, and emulsifiable concentrates also affect short-term behavior of a pesticide. For example, about 30 times more wettable powder will leach from the soil surface than emulsifiable concentrate if both are applied before a rainfall. (Deer, 1988)

The persistence of a pesticide affects its leaching potential by determining how much of the pesticide remains by the time that it reaches the ground water. The method of application and specific atmospheric degradation factors such as volatilization and photodegradation may substantially reduce the amount of the pesticide that enters the soil. Some pesticides may persist in or on plants and degrade rapidly when released to the soil. The soil degradation characteristics of a pesticide will depend upon such factors as soil moisture, temperature, soil oxygen status, and soil microbial populations.

Pesticide solubility affects its leaching potential by influencing the concentration of the pesticide in rain water which leaches. In general, pesticides with solubilities of less than 1 ppm will tend to be very resistant to leaching.

The sorption characteristics of a pesticide affects the leaching potential of a pesticide by delaying the transport of the pesticide through soils. This characteristic is usually described in terms of a K_{oc} value. This value measures the affinity of the pesticide to soil particles. K_{oc} values of 1000 or more have a high degree of affinity to the soil and will tend to move very slowly through the soil.

Through an SMP, as a preventive measure, a State may encourage the use of pesticides with low leaching potential or may choose to limit or prohibit the use of a pesticide with a high leaching potential in sensitive hydrogeologic settings. In addition, a State may actively investigate and encourage the use of pesticides that would provide the required pest control but are less susceptible to leaching.

Irrigation Practices

Irrigation strategies used in conjunction with pesticides can affect pesticide transport to ground water. Irrigation methods, timing, volume, and frequency may all affect whether pesticides may leach to ground water. In general, irrigation methods should be chosen that best supply crop water requirements without causing excessive leaching. Standard methods of applying water to agricultural fields may be grouped into flood or furrow irrigation, sprinkle irrigation, and trickle or drip irrigation.

Flood irrigation covers the surface of an entire field section with irrigation water while furrow irrigation applies water to earthen channels between crop rows. In both instances, infiltration of the ponded water is limited by the hydraulic conductivity of the soil, which may vary substantially in different parts of the field. Therefore, less restrictive soil pathways may be present that would allow differential infiltration and leaching during irrigation events. Less restrictive soil pathways that can increase water filtration in soils commonly include worm channels and root channels left from decayed crops. In addition, macropore spaces can develop during soil wetting and drying, freezing and thawing, animal activity, and tillage practice.

Sprinkle irrigation systems function by spraying irrigation water onto fields. Sprinkle irrigation systems impact ground water by washing foliar-applied pesticides from plant surfaces and promoting soil infiltration. For this reason, degradation rates, plant uptake rates, and irrigation schedules should be considered when planning pesticide applications.

Trickle or drip irrigation systems function by applying water slowly to points either directly on or beneath the soil surface. These systems are designed to apply irrigation water to localized areas where crop roots are present. Localized application, if done properly, reduces the amount of leaching over methods that apply irrigation water to the entire field surface.

Chemigation is the term applied to the practice of injecting farm chemicals into irrigation water before it is applied to cropped fields. Problems associated with chemigation generally arise from mixing pesticides at irrigation wells and the direct contamination of ground water through backsiphoning incidents (U.S. EPA, 1988). EPA requires registrants of pesticide products to include specific use directions and statements for application through irrigation systems (U.S. EPA, 1987). Several States are moving to require a minimum set of safety features for use in chemigation systems.

The **State of Florida's** Pesticide Law explicitly requires anti-backsiphoning devices, check valves, pressure switches, and metering pumps. Additional precautionary features are specified if the irrigation water source comes from a public water system. Requiring such a consistent set of safety features can be of great value if a State moves to institute a system of field inspections. Clear specification of the required safety equipment simplifies the job of the inspector. Having explicit requirements for safety devices also simplifies the task of conducting training programs for irrigators and pesticide applicators.

Through an SMP, a State may encourage the use of pesticide application schedules and techniques compatible with specific irrigation practices. This management practice would restrict the use of leachable pesticides to periods when irrigation waters are not migrating through the soil.

Timing of Pesticide Applications

Leaching of pesticides to the ground water from non-irrigated croplands is likely to be a more serious problem in many States than leaching associated with irrigation practices. Most U.S. cropland is not irrigated but still is subject to potential leaching caused by natural rainfall. Unlike irrigation, rainfall cannot be scheduled to accommodate pesticide applications. However, the potential for pesticide leaching may be reduced by adjusting the timing of pesticide applications to avoid predicted rainfall. In practice, this approach requires knowledge of impending pest problems before immediate action is required to allow flexibility in application timing.

Through an SMP, a State may establish guidelines that discourage the use of specific pesticides during a specified time period preceding predicted rainfall. In areas which receive large amounts of rain with little warning during certain times of the year, a State may choose to restrict the use of certain pesticides with a high leaching potential during those periods.

4.2.4 Measures that Reduce the Quantity and Toxicity of Pesticides Used and Integrated Pest Management

Integrated Pest Management (IPM) is a pest population management system that anticipates damaging levels by using techniques such as natural enemies, pest-resistant plants, cultural management, and judicious use of pesticides (National Research Council, 1989). IPM can significantly reduce the application of pesticides to crops, thus reducing the risks of pesticide contamination of ground water (Bender, 1990). The USDA estimated that agricultural pesticide use could decrease by as much as 40 percent through widespread use of IPM techniques (USDA, 1985). A current information source on the subject is the USDA bibliography on Water Quality Implications of Conservation Tillage, available through the National Agricultural Library and the AGRICOLA data base.

> For many crops with high per-acre rates of return, self-sustaining local IPM programs have been highly successful. Some of the best examples are in fruit growing areas. The **New Hampshire Fruit Growers' Association** worked for years with the Cooperative Extension Service to promote IPM initiatives (Wood, 1990). These efforts have proved so successful that conventionally managed orchards are rare in New Hampshire.

Knowledge of the surrounding environment is necessary to implement an effective IPM program. Extension specialists or pest control experts should be consulted when implementing IPM programs. Factors considered when designing and implementing IPM programs include:

- Understanding crop development cycles;
- Understanding crop cultural requirements during different growth stages;
- Understanding the economics of crop production and marketing;
- Identifying pests and understanding their impact on targeted crops;
- Understanding how much pest damage can be tolerated before a pest control action is justified (called the economically tolerable threshold level);
- Understanding the pest life cycle and the most effective time to implement pest control measures;
- Understanding the methods and materials required to suppress the targeted pest species most effectively; and
- Understanding pest control impacts on the ecosystem.

Over the past decade, the main public support for IPM programs came from the USDA Cooperative Extension Service in combination with research and technical services provided by State land grant universities and their local agricultural extension systems (Balling, 1990). Federal activities encouraged ongoing technical support services at the State level and promoted the formation of local self-sustaining IPM organizations.

> Support through EPA and the USDA, through the **Nebraska Cooperative Extension Service**, helped farmers establish the Long Pine IPM Program. This Program provides a framework to pool the costs of needed technical services. In the early stages, technical support was derived from a variety of USDA programs through the ASCS and SCS. The Program continues to receive technical assistance from the Nebraska Cooperative Extension Service, but the Long Pine IPM Association is now largely self-sufficient at the end of its 6-year involvement in the Rural Clean Water project (U.S. EPA, 1989).

The hallmarks of IPM programs are scouting and biological pest control measures. These measures and others that provide alternative solutions to the problems caused by agricultural pests are discussed in the following sections.

Reducing Pesticide Use Through Scouting

In assessing methods that reduce risks of pesticide contamination resulting from routine agricultural use, EPA concluded that the most effective means of protecting ground water resources is by reducing pesticide use (U.S. EPA, 1988). One of the most effective ways of reducing pesticide use, on a farm-to-farm basis, is through scouting practices. Scouting involves inspecting a field for pests and determining the extent of pest infestation. Scouting assessments allow farmers to choose the appropriate measures to effectively mitigate pest infestation problems. One direct benefit of scouting is identifying the stages of pest development, allowing for treatment during the pest's most susceptible lifecycle stage. By applying pesticides when the pest is most vulnerable, the quantity of pesticides required will decrease and may subsequently reduce or eliminate the need for follow-up applications. Many farming practices include the use of pesticides as preventative measures against possible future pest infestations. Scouting also monitors pest populations and resultant crop damage to enable managers to apply pesticides only when needed. If crop damage is within the economically tolerable threshold level and knowledge of the pest's lifecycle determines that an infestation is not imminent, unnecessary pesticide applications may be avoided.

> The **Michigan Department of Agriculture** assisted scouting activities as part of the Michigan Energy Conservation Program (MECP). Funding came from federal court settlements involving oil overcharges during the petroleum price controls of the 1970s. Promoting IPM programs was one of the six main uses of these funds (Draeger, 1990). Although oil overcharge funds for the MECP have not been available since 1991, past activities directed toward organizing local landowner groups and training scouting personnel resulted in several ongoing local programs.

A successful scouting program requires trained personnel who can reliably sample the pest population and interpret field measurements that relate to the population dynamics of pests and relevant predator or parasite species. Scouting programs often become self-sufficient after providing initial assistance. Often, the main hurdle is to involve a sufficient number of farmer-operators to share the costs of technical services, because individual landowners cannot usually afford scouting services. Although trained professionals generally are needed to initiate a scouting program, farmers can acquire the needed field sampling and interpretation skills. Over time, therefore, the costs of the program should decrease.

States should consider the examples set by Nebraska and Michigan of using one-time grants or other nonrenewable funding as a type of capital investment to organize critical components of IPM programs in developing SMPs.

Biological Pest Control

The use of chemical agents to control crop pests may eventually reduce the chemical's effectiveness due to increasing tolerance by the pests. In addition, the effect of many chemical agents is not restricted to the target pest and may also harm natural predators or parasites of the pest. Biological control techniques aim to enhance natural mechanisms that control pests at economically tolerable threshold levels (OTA, 1990). Several types of natural biological pest controls are available to growers. Controls such as antagonists, increasing the populations of predators, and self-defense mechanisms are successful with many pests. Bolstering natural enemies (e.g., parasites, predators, and insect pathogens) are usually partially effective in limiting the population sizes of pests.

In addition to manipulating natural food chain relationships, other methods of biological pest control include importing and releasing exotic natural enemies, increasing indigenous natural enemy populations, introducing insect diseases, and introducing insect pheromones. For example, widespread use of Bacillus thuringiensis, a bacteria which eat larvae, effectively controls gypsy moth infestations.

> One of the earliest applications of biological agents was the 19th century use of the Vedalia lady beetle to control cottony-cushion scale on citrus in California. **The State of California**, chiefly through long-standing research programs, has been a leader in promoting biological controls. In addition to the use of predators, considerable success has been achieved by using such species as chalcid wasps, whose young are parasites on a variety of insect pests.

Many States release irradiated (and therefore sterile) male pest species to reduce normal reproduction rates. This technique has been widely used in California on the Med-fly and in Texas on the screw worm. Similar results are often be obtained by introducing chemicals that mimic the properties of pest pheromones. These synthetic hormones interfere with pest mating success and serve to control populations at tolerable levels. Pheromones (or similar behavior-affecting agents called semiochemicals) can be placed in bait attractors mixed with minute quantities of pesticides to achieve carefully targeted control of pests. Such approaches were very successful in treating corn rootworm in South Dakota (Madden and O'Connell, 1990).

Pest-Resistant Plant Varieties

Another method for limiting pesticide use is through strategic selection of crop variety. This nonchemical practice is rapidly becoming the most-used form of pest control in the United States. By one estimate, as much as 75 percent of the total U.S. crop-producing acreage is planted with pest-resistant and disease-resistant plant varieties (U.S. EPA, 1988). In addition, considerable research is underway to develop crops that have heightened resistance to pests (National Research Council, 1989).

Pest-resistant plant varieties can either suppress pest infestation or recover from pest damage. Use of pest-resistant varieties, in conjunction with other agricultural practices such as scouting, tillage, and crop rotation, may effectively reduce the quantity of pesticides used.

Tillage Practices

Tillage practices are generally employed to improve soil conditions for planting and crop growth, and to disrupt weed growth. The type and timing of tillage practices minimizes the amount of pesticides used by mechanically disturbing or destroying crop pests or by more effectively bringing the pesticide in contact with the pest. However, tillage operations increase the susceptibility of the surface soil to erosion and to possible pesticide loss to surface waters (U.S. EPA, 1988). Conservation tillage techniques have been developed to reduce both the rate of soil erosion and of herbicide use and can reduce pesticide loss to surface waters. The use of conservation tillage techniques, however, generally results in an increase of infiltration water. This results in more water in the soil profile, which may increase the leaching potential of pesticides. The term conservation tillage is often used to refer to such methods as no-till, ridge-till, strip-till, mulch-till, and reduced-till. A full description of these methods may be obtained from the Conservation Technology Information Center (1987). *Some reduced tillage techniques may require increased dependence on chemical pest control measures which leads to increased pesticide usage. Therefore, careful consideration of the potential impacts to ground water must be made in determining tillage practices.* In many cases, tillage used in combination with other management techniques such as contour farming, terracing, or crop residue management helps minimize the potential for both surface and ground water contamination by pesticides. (A bibliography of sources is available in USDA 1991, QB 91-145.)

Crop Rotation and Stripcropping

Crop rotation is the successive planting of different crops in the same field over a period of years. Pest control is the most significant impact of the crop rotation process. Crop rotation may serve to minimize pesticide usage by avoiding the buildup of pest populations that may result from continuous cropping of a specific or similar crop. Without an initially large pest population, the crop has a head start to become established and better compete with pests before the pest population increases to the point that it significantly damages the crop.

Stripcropping is a method that combines crop rotation with contour planting. It involves rotating alternating strips of crops that are planted parallel to the contours of the field. If one strip is of a relatively open field crop, such as corn, the other strip is usually a grain crop, a sod, or a legume. The primary agricultural advantage of stripcropping is generally considered to be the reduction of soil erosion and surface runoff. The benefits of crop rotation such as insect, weed, and nematode reduction are also associated with stripcropping practices (Maas et al., 1984). In combination with tillage practices, stripcropping and crop rotation can significantly reduce the quantity of pesticides necessary to maintain a crop (U.S. EPA, 1988).

Increasing Pesticide Application Efficiency

By increasing application efficiency, the total amount of pesticide needed to control pest problems may be reduced. Highly efficient applications would concentrate the pesticide on the target pest while minimizing the total amount of pesticide used. Pesticide application techniques that reduce or avoid losses through wind drift and selectively place the pesticide provide greater application efficiency. Some examples of application systems that provide increased efficiency are:

- Directed drop nozzle spray systems that apply herbicides to weeds under the crop canopy;

- Wick applicators control application to weeds that touch the wick, thereby avoiding application to nearby crop surfaces or the soil; and

- Recirculating sprayers that collect and reuse pesticide not intercepted by weeds.

Many different methods are available to apply pesticides that provide increased efficiency of application when specific pesticides and specific conditions are carefully considered.

4.3 Implementation Approaches

The preventive measures described above can be implemented through different approaches and by different levels of government. Implementation approaches include both:

- Non-regulatory efforts; and
- Regulatory actions.

In addition, preventive measures can be implemented at different levels of government, including:

- Federal;
- State;
- Local; or
- Special district.

A critical SMP component are contingency preventive measures that provide for increasingly stringent controls on pesticide use when evidence indicates that initial preventive measures are inadequate or have failed. In addition, areas of high vulnerability may require increasingly preventive measures, even though the pesticide has not been detected in ground water. A State should consider the need for increasingly stringent preventive measures developing its prevention plan and selecting its implementation approaches.

> The approach proposed by the **Minnesota Department of Agriculture** for management of atrazine relies on voluntary measures so long as pesticides are not found in ground water at or above a designated action level. If BMPs are not effective in prevention, then additional mandatory efforts may be required (Minnesota Department of Agriculture, 1990b).

4.3.1 Non-Regulatory Efforts

States can use non-regulatory efforts to implement a variety of SMP preventive measures. No penalties are assessed for noncompliance with non-regulatory requirements, thus, allowing the farmer or pesticide user maximum flexibility in the selection of appropriate practices for field-specific conditions. Non-regulatory efforts include:

- Information dissemination;
- Public education and outreach;
- Planning and technical assistance; and
- Financial assistance (cost-share and loans).

Information Dissemination

Pesticide users are in the unique position of directly controlling the use of a pesticide. For this reason, States should target users when disseminating information on preventive measures. Examples of such programs include farmstead assessment programs developed by many States, using the Farm-A-Syst model described earlier as the starting point. These State pollution prevention tools enable farmers to analyze the individual and combined effects on drinking water sources of farmstead activities and structures, local soil and geologic features, and water-supply characteristics. These programs also enable farmer development and implementation of action plans to reduce identified risks. Because the programs are voluntary they are viewed positively by participants and the participants are more willing to conduct and implement assessments because they know that the results are for their use.

Under Component 11 of an SMP (Information Dissemination), SMP preventive measures must be communicated to pesticide users and appropriate industry groups and regulatory officials. These programs often rely on federal, State, and university specialists to provide technical assistance and information on the leaching potential of pesticides and associated preventive measures.

One example of such a program is the Farmstead Assessment System (Farm-*A*-Syst) pilot project undertaken by the **University of Wisconsin Extension, USDA Cooperative Extension Service, Minnesota Extension Service, and EPA - Region 5**. Farm-*A*-Syst consists of a series of 12 worksheets designed to help farmers assess the effectiveness of farmstead practices in protecting drinking water. The system enables farmers to analyze the individual and combined areal effects of farmstead activities with local soil, geologic features, and water-supply characteristics on drinking water supplies. More information on the Farm-*A*-Syst program may be obtained from Susan Jones, Farm-*A*-Syst Program, B142 Steenbock Library, 550 Babcock Drive, Madison, Wisconsin 53706-1293. The telephone number is (608) 262-0024.

Public Education and Outreach

Non-regulatory preventive measures typically focus on public education about which measures are effective in preventing pesticide contamination of ground water. Component 10 of an SMP requires a State to demonstrate that the public will have access during SMP development and will be informed of significant implementation activities. Public education and outreach efforts should communicate to general public concerning the State's pesticides management efforts.

Planning and Technical Assistance

Some of the preventive measures described above, such as Integrated Pest Management (IPM), require long term planning by farmers. In addition, many farmers need technical assistance to implement some of the IPM preventive measures. A State should consider using planning and technical assistance as an implementation approach to reduce the use of pesticides within the State. Technical assistance is also a useful tool in implementing preventive measures for rural water well construction and abandonment.

4.3.2 Regulatory Actions

At times regulatory actions may be necessary to ensure proper implementation of SMP preventive measures. Penalties could be assessed for noncompliance with regulatory requirements, and these requirements, therefore, allow the State to enforce the requirements of an SMP and better control sources of contamination. Regulatory efforts include:

- Certification programs;
- Permits and advance notice;
- Land use controls; and
- Enforcement activities.

State Certification Programs for Pesticide Applicators

The EPA Office of Pesticide Program's Certification and Training (C&T) program assists State FIFRA agencies, State land grant universities, and the USDA Cooperative Extension Service training programs for certification of commercial and private pesticide applicators.[1] Training initiatives are widely viewed as desirable because approximately half the actual applications of restricted-use pesticides are carried out by noncertified assistants (OTA, 1990).

> An overview of ground water information is presented in *Protecting Groundwater: A Guide for the Pesticide User*. The Guide is a slide set storyboard developed for use in certification and training courses. It can be purchased from the **New York State Water Resources Institute**. Copies may be obtained from the New York State Water Resources Institute, CER, 468 Hollister Hall, Cornell University, Ithaca, New York 14853; Telephone: 607-255-7535.

Whether administered by EPA or a State agency, under FIFRA, all States must have an EPA-approved certification program for pesticide applicators so applicators can legally use restricted-use pesticides. EPA classifies a pesticide in the restricted-use category if the pesticide may cause unreasonable adverse effects on the environment or injury to the applicator.

> **Florida** has had requirements for applicator certification and testing for restricted use pesticides since 1977. Additions to the Florida Pesticide Law in the mid-1980s extended basic C&T requirements for restricted-use pesticides to applicator assistants (Florida Department of Agriculture and Consumer Services, 1989).

> **California** has a well-established licensing and certification program for hired applicators or for applicators of restricted-use pesticides. Licenses and certificate holders have a continuing education requirement which affords term an opportunity to obtain information on ground water protection. Similarly, California has a ground water protection training program for pest control advisors that write ground water protection advisories for known leachers. These advisories pertain to the use of known leachers in designated sensitive areas. The training program for pest control advisors must be repeated every two years. This C&T program is of great value in California's system of Pesticide Management Zones (PMZs).

[1] Further information on applicator certification may be obtained from EPA's Office of Pesticide Programs, Certification and Training Office; Telephone: (703) 305-7371.

State certification training programs should provide sufficient coverage of a number of elements, including ground water contamination by pesticides. The ground water component of the course should define ground water, its importance, factors that determine whether a pesticide will reach ground water (e.g., geology, hydrology, climate), steps to avoid ground water contamination, pesticide characteristics that affect potential ground water contamination, and the consequences of contaminating ground water.

Alternatively, a State certification program could be used as a forum to describe the SMP requirements, including restrictions on pesticide use in certain areas. Because ground water vulnerability varies with local hydrology, geology, and pesticide use, States should discuss these local conditions with participants.

Permits or Advance Notice Programs

Permits can be required for pesticides in areas which are susceptible to leaching or for certain pesticides in the entire State. Some States require that certain pesticides be used or purchased only under a special permit from the State's Department of Agriculture. Permit applications are usually required in writing, but oral applications are sometimes accepted. Permit applications typically request information such as the name and address of the pesticide applicator; name and formulation of the pesticide; where, when, and quantity of the pesticide; method of application; and special controls or precautions that will be exercised in the use of the pesticide.

Land Use Controls

Restricting the use of a pesticide in certain geographic areas is a stringent preventive measure designed to limit pesticide contamination of ground water in high value and vulnerability areas. Another land use restrictions is limiting storage and disposal of pesticides to certain areas. As an implementation approach, land use controls can effectively protect against pesticide contamination of ground water. In developing an SMP, States must consider, however, that local governments traditionally are responsible for instituting land use controls, such as zoning.

Enforcement Activities

Enforcement activities might become necessary to ensure compliance with preventive measures and to control contamination sources. The SMP approach is based on the premise that pesticide management and enforcement is best conducted at State and local levels. A State should place emphasis on coordinating FIFRA, SDWA, RCRA, and CERCLA enforcement activities of EPA-delegated programs as well as those administered by EPA to identify responsible parties for ground water contamination as a result of the misuse of pesticides, including disposal or leaks and spills.

Component 9 of an SMP, Enforcement Mechanisms, requires a State to describe enforcement and compliance activities, including inspection, technical support, voluntary compliance efforts, and penalty provisions. In addition, a State must discuss its enforcement authorities and capabilities to monitor compliance with the specific measures included in the SMP.

4.3.3 Involvement of Each Level of Government

Different levels of government can implement the preventive measures and implementation approaches outlined.

Federal Level

Because of each State's unique hydrogeologic, institutional, and demographic characteristics, EPA believes that they are in the best position to manage specific pesticide use. Therefore, EPA believes that delegation of certain pesticide management authorities to the appropriate State and local officials is desirable. To timely ensure protection of ground water from pesticides contamination, EPA will move to actively review and approve SMPs (See Appendix A).

EPA and USDA also provide technical and financial assistance that helps States develop and implement preventive measures. Chapter 7 provides a detailed discussion of sources of technical and financial assistance from both EPA and USDA.

USDA is currently implementing a number of new programs that are consistent with the preventive measures of SMPs. These include:

- Base Flexibility. The "base flexibility" in the 1990 Farm Bill allows farmers who participate in federal commodity support programs to rotate crops and plant a greater variety of crops on acres that were previously tied to a specific crop. This change is expected to lead to reduced pesticide and fertilizer use, since crop rotation, especially with nitrogen-fixing legumes, is a recognized means for reducing the need for artificial nitrogen fertilizer and for breaking the pest infestation cycles that affect repeated plantings of the same crop;

- Cost-Share. Cost-share programs will be offered to producers, certain hydrologic units, and demonstration project areas across the United States. Financial assistance will be coupled with intensive education and technical assistance to encourage the adoption of environmentally sound practices and the achievement of area-wide improvements in protection of water quality;

- Agricultural Conservation Program. The Agricultural Conservation Program supports special water quality projects focusing on water quality problems identified by State and local water quality planning agencies;

- Water Quality Incentive Program. The Water Quality Incentive Program provides farm-level planning to reduce the use of fertilizer, other crop nutrients, and pesticides to achieve water-quality objectives. Participants receive incentive payments designed to compensate for additional production costs and/or foregone production values; and

- The Conservation Reserve Program. The 1990 Farm Bill also provides specific authority to enroll land in the Conservation Reserve Program under water-quality criteria. The program is used to enroll land in high priority watersheds, wellhead protection areas, and other areas that, if taken out of production, would contribute to protection of water resources.

State Level

EPA recognizes State governments as the appropriate level of government to implement the provisions of an SMP. The Guidance Pesticides and Ground Water State Management Plans provides the necessary flexibility for States to develop and implement individually-tailored SMPs, but also ensures that States are accountable for the proper management of a specific pesticide to protect against pesticide contamination of ground water.

The preventive measures outlined above can be implemented and supported at the State level by participating regulatory agencies. Many of the measures, such as limitations and restriction, are generally best managed by the State. In addition, a State has the flexibility to determine who will be responsible for implementing specific preventive measures (Components 2 and 3).

Local Level

Local governments can also play a beneficial role in protecting ground water through SMPs. Local governments are already involved in other water quality programs such as Wellhead Protection Programs and Public Water Supply Programs. Local governments can support State efforts in information dissemination and public education and outreach.

Local governments can support the SMP through land use controls, such as storage and disposal restrictions. Local governments can also provide technical assistance to rural well owners and operators to control direct sources of ground water contamination through wells.

Special District Level

Special districts exist for soil conservation and other agricultural activities. These agricultural districts can support public outreach and technical assistance in the field. The activities of these districts often include direct involvement with local farmers and can provide a suitable forum for providing information to the regulated community.

4.4 Implementation Considerations

The preventive measures summarized in Section 4.2 and the implementation approach summarized in Section 4.3 may be considered individually or in conjunction with other measures and approaches to protect ground water. No single preventive measure or implementation approach will be appropriate or equally effective in all situations. When developing and implementing an SMP prevention plan, a State should consider the following factors in the selection of preventive measures and implementation approaches:

- The effectiveness of a preventive measure in protecting ground water resources;
- The cost of instituting preventive measures;
- The geographic areas in which preventive measures should be implemented;
- The effects that ground water protection measures might have on other resources; and
- The use of reference points or action levels to determine appropriate preventive measures to the levels of risk.

The stringency of preventive measures should be appropriate to the level of protection needed. In general, areas of high ground water sensitivity and/or high pesticide use will necessitate more stringent preventive measures. Conversely, in areas characterized by low ground water vulnerability, less stringent preventive measures may suffice to protect ground water. If pesticides are detected in ground water, the stringency of preventive measures should increase as the number of detections or concentrations approach a reference point (e.g., MCL, health advisory, interim health limit, or State action level). Some factors to consider in developing and implementing preventive measures of SMPs are presented below. In addition, examples of ground water and surface water priority ranking systems are provided by Bottcher and Baldwin (undated), USDA (1990), and Brach (undated).

4.4.1 Effectiveness for Ground Water Protection

A State evaluates the effectiveness of preventive measures through its monitoring programs (Chapter 5). The effectiveness of preventive measures will vary with different agricultural, hydrogeologic, and physical situations. A State's monitoring program should provide necessary information on the effectiveness of current preventive measures. If a State's monitoring program finds a prevention program ineffective through detection of pesticides in ground water, then the State implements increasingly stringent preventive measures. In some cases, an evaluation of effectiveness is best judged for groups of practices rather than for a single preventive measure.

4.4.2 Economic Costs

States should select prevention practices that are effective in protecting ground water as well as cost effective to implement. For example, if a rate reduction of a specific pesticide is to be implemented, States should select an application rate that is still effective in reducing pests. Economic factors that should be considered in ranking prevention options include:

- **Probable cost of pesticides to farmers.** A lower application rate for a specific pesticide may reduce the total volume of the pesticide applied thus lowering the cost of pesticide application. Changing the pesticide used, however, may or may not increase costs to the farmer depending on the cost of the alternative pesticide.

- **Impact on crop yield and quality.** The reduction in pesticide application rates may increase the occurrence of insects, rodents, or weeds resulting in lower crop yields and/or quality.

- **Labor or special equipment requirement.** Additional labor may be required to reduce the application rate of the specified pesticide or to apply an alternative pesticide. New or upgraded equipment may be necessary to reduce the application rate or to change to an alternative pesticide (Brach, undated).

4.4.3 Geographic Extent

State protection priorities should be based, in addition to ground water vulnerability, on the use and value of the ground water resources. Determining where to implement preventive measures requires an understanding of aquifer sensitivity and pesticide use (Chapter 3). As a result, implementation of preventive measures will vary across the State. The geographic application of preventive measures may present a problem, since what may be applicable to a region may be inappropriate on a farm-specific basis.

For example, the voluntary atrazine best management practices proposed by the **Minnesota Department of Agriculture** include application rate restrictions to areas of the State where fractured rock aquifers (including karst conditions) or sand, loamy sand, or sandy loam soils predominate (Minnesota Department of Agriculture, 1990b). Counties within Minnesota that meet these conditions are specified. The user is cautioned, however, that areas in every county of Minnesota may include one of these conditions. In addition, atrazine management practices for all areas of the State include timing restrictions (i.e., application of atrazine may only occur between the spring thaw and the time that corn plants reach 12 inches in height), distance limitations or buffer zones around sinkholes and drainage wells, irrigation management measures, and container management measures.

Some types of management measures are more appropriately applied to either large or small areas. Small geographic areas are most effectively micromanaged with field-specific restrictions or permitting measures. Conversely, larger geographic areas are more effectively managed with area-specific restrictions. Regional implementation of preventive measures, therefore, should include sufficient flexibility to allow for local variations in aquifer sensitivity and pesticide use. An assessment of the scale to which individual prevention practices reasonably and effectively apply may help determine the priorities and selected options.

Another example States may wish to consider is to utilize management measures such as Farm-A-Syst type pollution prevention programs by specifically targeting the programs to geographic areas of greater vulnerability to ground water contamination, or where greater protection is warranted. For example, municipalities with farmsteads located in or near public water supply wellhead protection areas may take extra measures to prevent contamination by using farmstead assessments.

An example of geographic applications is the approach used in **Wisconsin** to manage aldicarb and atrazine use. Aldicarb is used in small geographic areas (approximately 60,000 acres) of the State. The management plan reflects this in instituting field-specific use restrictions. Conversely, atrazine is the most commonly used agricultural pesticide in Wisconsin and is applied to approximately 3.5 million acres. For this reason, site-specific use restrictions have been instituted in recharge areas to major aquifers in Wisconsin. Also, Atrazine Management Areas have been established covering larger geographic areas to manage the use of this pesticide. Further information concerning pesticide management plans in Wisconsin may be obtained by contacting the Wisconsin Department of Agriculture, Trade, and Consumer Protection, 801 West Badger Road, Post Office Box 8911, Madison, Wisconsin 53708-8911; Telephone: (608) 266-2295.

4.4.4 Impacts on Other Media

The effectiveness of a particular preventive measure at preventing ground water contamination may be directly related to the contamination of other media, most notably surface water. The SMP approach closely links other programs that promote environmental quality and reduces risks associated with pesticide use. Such issues as the effects of individual practices on soil erosion, the quality of field runoff that may impact surface water, accumulated pesticides in foods or plant residues, and air quality should therefore be considered. An environmental quality assessment of the impacts of prevention practices in the area may be derived based on consideration of impacts on individual media (e.g., plants, soils, surface waters, and air).

4.4.5 Use of Reference Points or Action Levels

Consideration of preventive measures overlaps with monitoring (Chapter 5) and response measures (Chapter 6) when pesticides are detected in ground water. As noted in Section 4.1, the stringency of preventive measures to protect ground water from pesticide risks should increase with increased aquifer sensitivity and as concentrations of detected pesticides approach reference points. For this reason, the establishment of reference points or action levels that trigger specific prevention and response measures is a necessary prelude to the development of both prevention and response plans.

The EPA has promulgated Maximum Contaminant Levels (MCLs) for some pesticides and compliance monitoring requirements for public water-supply systems. These are part of the National Primary Drinking Water Standards authorized under the Safe Drinking Water Act (40 CFR Part 141). Many States use the same criteria for management of private water-supply wells. The EPA Office of Marine and Estuarine Protection sets water quality standards for some pesticides under the Clean Water Act.[2] These standards may be used as reference levels for ecological effects of pesticide contamination.

EPA will continue to emphasize the development and enforcement of MCLs and Health Advisories (HAs) to ensure the quality of ground water and drinking water supplies. EPA encourages States, however, to establish their own reference points or action levels at fractions of these federal enforcement standards. Detections below reference points should also trigger preventive actions to prevent contamination with the potential to pose risks to human health and the environment. The SMP must indicate the factors and rationale considered in choosing these measures and the triggers that would lead to a State's implementation of more stringent measures. At a minimum, confirmed detections of a pesticide in ground water should be treated as a cause for concern and trigger an assessment of the cause of contamination and an evaluation of the effectiveness of existing preventive measures.

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[2] For further information on water quality criteria and standards for aquatic life, contact EPA's Office of Wetlands, Oceans and Watersheds at (202) 260-7166.

4.5 References

Aller, L., T. Bennett, G. Hackett, R.J. Petty, J.H. Lehr, H. Sedoris, D.M. Nielsen, and J.E. Denne. 1990. Handbook of Suggested Practices for the Design and Installation of Ground Water Monitoring Wells. National Water Well Association. NTIS PB90-159807. 455 pp.

Bender, J. 1990. "Converting to Pesticide-Free Farming: Coping with Institutions." *Journal of Soil and Water Conservation* 45(1):96-98.

Bottcher, A.B., and L.B. Baldwin. Undated. General Guide for Selecting Agricultural Water Quality Practices. Florida Cooperative Extension Service; Pamphlet SP-15. 5 pp.

Brach, J. Undated. Agriculture and Water Quality: Best Management Practices for Minnesota. Minnesota Pollution Control Agency. 64 pp.

Congress of the United States, OTA (Office of Technology Assessment). 1990. Beneath the Bottom Line: Agricultural approaches to Reduce Agrichemical Contamination of Groundwater. OTA F-418.

Conservation Technology Information Center. 1987. National Survey of Conservation Tillage Practices. National Association of Conservation Districts, Washington, D.C.

Deer, H.M. 1988. Pesticide Data on Potential Impacts to Ground and Surface Water. USDA Cooperative Extension Service, Utah State University.

Draeger, C.L. 1990. "Sustainable Agriculture at Work." *Journal of Soil and Water Conservation* 45(1):83-85.

Florida Department of Agriculture and Consumer Services. 1989. Florida Pesticide Law and Rules. Chapter 487, Florida Statutes. pp. 1642-1657.

Ganley, M.C. 1989. "Availability and Content of Domestic Well Records in the United States." *Ground Water Monitoring Review*, 9(4):149-158.

Maas, R.P., S.A. Dressing, J. Spooner, M.D. Smolen, and F.J. Humenik. 1984. Best Management Practices for Agricultural Nonpoint Source Control: Pesticides, National Water Quality Evaluation Project. USDA Cooperative Agreement 12-05-300-472; EPA Interagency Agreement AD-12-F-0-037-0. NTIS PB85-114247. 76 pp.

Madden, J.P. and P.F. O'Connell. 1990. "LISA: Some Early Results." *Journal of Soil and Water Conservation* 45(1):61-64.

Minnesota Department of Agriculture. 1989. "Pest Control." Chapter 18B, 1989 Minnesota Statutes. 32 pp.

Minnesota Department of Agriculture. 1990a. "1990 Amendments to 1989 Minnesota Statutes." 14 pp.

Minnesota Department of Agriculture, Agronomy Services Division. 1990b. "Proposed Voluntary Atrazine Best Management Practices." 2 pp.

National Research Council. 1989. Alternative Agriculture. National Academy Press, Washington, D.C. 448 pp.

USDA, Cooperative Extension Service. 1985. Cooperative Extension and Agricultural Profitability - Integrated Pest Management Reduces Costs and Increases Income.

USDA, Soil Conservation Service. 1988. Water Quality Field Guide. SCS TP-160.

USDA, ASCS/ES/SCS. 1990. Water Quality Education and Technical Assistance Plan: 1990 Update. Agriculture Information Bulletin No. 598. 13 pp.

USDA. 1991. Water Quality Implications of Conservation Tillage: January 1980-July 1991. National Agricultural Library, Quick Bibliography Series. QB 91-145.

USDA. 1991. Managing Nonpoint Sources of Pollution: January 1982-July 1990. National Agricultural Library, Quick Bibliography Series. QB 91-50.

U.S. EPA, Office of Ground Water Protection. 1987. Guidelines for Delineation of Wellhead Protection Areas. EPA 440/6-87-010.

U.S. EPA, Office of the Administrator. 1992. Final Comprehensive State Ground Water Protection Program Guidance. EPA 100-R-93-001.

U.S. EPA. 1987. Notice to Manufacturers, Formulators, Producers, and Registrants of Pesticide Products. PR Notice 87-1. 17 pp.

U.S. EPA, Office of Ground Water Protection. 1988. Protecting Ground Water: Pesticides and Agricultural Practices. EPA 440/6-88-001. NTIS PB88-230628. 53 pp.

U.S. EPA, Office of Water, Nonpoint Sources Branch. 1989. Rural Clean Water Program 1988 Workshop Proceedings. EPA 506/9-89/001.

Wisconsin Administrative Code. 1985. "Agriculture, Trade, and Consumer Protection," Chapter Ag 161. Fertilizer or Pesticide Substances in Ground Water: Regulatory Program. Register, No. 357. pp. 667-680.

Wisconsin Department of Natural Resources, Bureau of Solid Waste Management. 1985. Guidelines for Monitoring Well Installation, Appendix B. 35 pp.

Wood, S. 1990. "The Trials of a Fruit Grower." *EPA Journal* 16(3):37-40.

Chapter 5

Monitoring Elements of SMPs

Ground water monitoring plays an integral role in reducing and preventing the future degradation of ground water from pesticide contamination. Monitoring is likewise an integral part of evaluating the effectiveness of any mitigation measures taken. Under the SMP approach, ground water monitoring is an ongoing activity which enhances a number of preventive functions, including defining background ground water quality, identifying contamination occurrences, evaluating the effectiveness of implemented ground water protection measures, and assessing the success of response measures. Monitoring is one tool, which used along with other tools, can assess where areas of contamination exist. As a first step towards developing a monitoring program, States can use existing wells to form a network to begin gaining baseline information on pesticide contamination of ground water. It will take time for the results of preventive measures to become apparent.

The Guidance for Pesticides and Ground Water State Management Plans provides that both a State's Generic SMP and Pesticide SMP should:

- Describe the State's monitoring program for pesticides and pesticide degradates (breakdown products or metabolites); the uses to which monitoring will be applied; and the parties responsible for various functions associated with monitoring. Key elements of a monitoring program must include scope and objective, design and justification, monitoring protocols, quality assurance/quality control, sampling methodology, analytical methods, and analytes.

In addition to the Generic Plan Criteria listed above, a Pesticide Plans must:

- Describe the purpose of each specific monitoring protocol. For example, SMP monitoring may be used (1) to confirm detections at specific sites; (2) to define the extent of the problem at a specific site; and/or (3) to evaluate the quality of ground water on an annual basis. Each SMP would describe, for each of the three uses, the specific monitoring protocols to be used and who will conduct sampling, analysis, quality assurance/quality control, etc.

- Include specific monitoring designs and justifications that address the number of sites to be sampled, the number of samples to be taken, the frequency of sampling, and the analytical methodology that will be used to evaluate the samples. Quality Assurance/Quality Control measures must be provided. Monitoring data collected by the State should be of known and reliable quality and properly stored for retrieval and use. (See Component 12)

Figure 5-1. Range of Technical Tools for Developing a Monitoring Program

	Type of Monitoring	Monitoring Design & Justification	Sampling Procedures	Sample Analyses
▲	• Evaluation Monitoring	• Stratified sampling based on known hydrogeology and pesticide use characteristics of State		• Analysis for numerous pesticides and degradates
			• Sampling with data collection follow-up for detections	
Pesticide SMPs	• Response Monitoring	• Random sampling with stratification on areas of known presence of pesticide of interest in ground water		
▲	• Problem Identification Monitoring	• Random sampling with limited number of analyses and sampling events		• Use of multi-residue methods with qualitative and quantitative confirmation
		• Use of existing wells and limited number of new monitoring wells across State	• Time-series sampling	
	• Baseline Monitoring	• Use of existing wells and limited number of new wells in selected locations		• Use of multi-residue methods with qualitative confirmation
Generic SMPs		• Use of existing observation wells; water supply wells; seeps and springs; and piezometers	• One-time sampling	• Analyses for small number of analytes -- Immunoassays

- Include Quality Assurance/Quality Control measures as described in Section 5.4 of this Chapter.

- Describe how the placement of monitoring wells relates to the State's priorities for protecting ground water and how the placement will allow for evaluation of the effectiveness of prevention and response measures. (See Component 5).

Technical considerations for developing and implementing monitoring programs for SMPs are addressed in Sections 5.1 through 5.6. These sections provide technical tools and options used for developing the six elements of an SMP monitoring program.

5.1 Monitoring Program Scope and Objective

The SMP monitoring program scope and objective is largely determined by whether the State develops a generic monitoring plan or focuses on monitoring for a specific pesticide. In the latter case, characteristics of the particular pesticide requiring a Pesticide SMP, such as physical factors (e.g., solubility and halflife), leaching potential, partition coefficients (K_{oc}) and volatility, can have a significant effect on the scope of monitoring which is necessary. For example, the scope of a monitoring program for a pesticide that is used widely throughout a State will be considerably larger than the scope for a pesticide whose use is limited to a small confined area of the State.

The monitoring scope and objective is influenced by the extent to which a State has the following information:

> Through implementation of the **Florida Water Quality Assurance Act**, the State established a ground water quality monitoring network. The network is a cooperative effort primarily of the Florida Department of Environmental Regulation and Federal and State agencies. The State's monitoring objectives are threefold: (1) to establish baseline ground water quality of major aquifers; (2) to detect and predict changes in ground water quality resulting from land-use activities and identified sources of contamination (including agricultural chemicals); and (3) to disseminate water quality data for use by government entities and the public. While Florida's monitoring strategy does not focus exclusively on agricultural chemicals, the design provides examples of baseline and response monitoring. Contact: Florida Department of Environmental Protection, 2600 Blair Stone Road, Tallahassee, Florida 32399-2400; Telephone: (904) 488-3601.

- **Hydrogeologic Conditions**. Monitoring of particularly sensitive ground water may depend on knowledge concerning the location of ground water recharge areas and sensitive or vulnerable ground water areas as well as geologic factors such as karst areas.

- **Pesticide Use**. Information that identifies the types and geographic locations of pesticide uses as well as application rates help to focus pesticide-specific monitoring. Data identifying cropping patterns may also be useful for extrapolating pesticide use.

- **Locations and Types of Existing Monitoring Wells.** Information about existing monitoring wells, including location (e.g., latitude and longitude coordinates) and well design (e.g., surface seal of well and well depth) will assist in planning monitoring programs.

The U.S. EPA Office of Research and Development (ORD), in a cooperative research agreement with the University of Iowa, is conducting a study, "Temporal Variability of Atrazine Contamination of Private Rural Well Water Supplies." This study:

- characterizes the differences between a one-time and multiple-time sampling study with respect to the extent of contamination, exposed population, and health risk implications of atrazine and nitrates; and

- develops statistical autocorrelation models that can be incorporated into a multiple-sample monitoring design (i.e., temporally, characterize a population of drinking water wells with respect to atrazine, pesticides in general, nitrates, and other ground water contaminants).

The study is designed to develop methodologies to appropriately monitor media for use in similar studies. To date, nearly all pesticides in drinking water well studies have not been designed with an intent to use the data in an exposure and risk assessment because they have neglected the temporal component of well water quality. *For more information, contact Matt Lorber, U.S. EPA Office of Research and Development, (202) 260-8924.*

For example, a State that collects information identifying pesticide use by geographic area and hydrogeologic conditions may be able to reduce the scope of monitoring for an SMP. These States can target their monitoring efforts to selected areas of known pesticide use and to areas that are sensitive or vulnerable to ground water contamination.

Ehteshami et al. (1991) developed a two-stage screening procedure for determining pesticide contamination in Utah's ground water. The procedure's first stage estimates a weighted average of a location's vulnerability to ground water contamination using a hazard to ground water hydrogeological screening model (DRASTIC). The DRASTIC model screens for vulnerable hydrogeologic sites. In the second stage, the location of the peak concentration of organic chemicals as the chemicals move through soil are estimated using the Chemical Movement in Soil (CMLS) model. The CMLS model screens pesticide/site combinations by simulating the rate of leaching of a particular pesticide in a specific physical/chemical environment. This two-stage approach increases the probability of locating pesticides in ground water and may reduce sampling needs by identifying sites which have the highest risk of contamination.

Because the scope and objective of a monitoring program takes into account the utilization of monitoring elements, the technical considerations discussed below should be used in developing the scope and objective element.

5.2 Monitoring Design and Justification

The principal objective of a monitoring well is to obtain representative ground water samples. Monitoring wells must be designed and installed according to exacting specifications to achieve the desired objectives and to maintain a high degree of confidence in the monitoring results. Poor monitoring well design and careless well installation procedures can significantly reduce ground water sample quality. Details of monitoring wells designed to monitor shallow aquifers are found in Guidance for Field-Scale Ground Water Monitoring Studies, developed by the EPA Office of Pesticide Programs.[1]

A ground water monitoring network for SMPs should include both new and existing wells. In general, the cost of developing new monitoring wells will prohibit most States from using only new monitoring wells. The development of a monitoring well network should identify the location and the quality of well construction to select the most appropriate existing monitoring points. In addition, States should identify new well locations to fill the monitoring gaps of the existing wells.

Sections 5.2.2 through 5.2.4 provide technical information on the use of existing wells, including water-supply wells (e.g., irrigation wells and public water-supply wells), monitoring wells, observation wells, and piezometers. Section 5.2.5 discusses factors States should consider in developing new monitoring wells. Section 5.2.6 discusses special considerations for ground water monitoring in karst terrains. Section 5.2.7 discusses special considerations when monitoring ground water in fractured rock terrains.

> **Florida's** monitoring network includes a separate component consisting only of private drinking-water wells. Seventy wells per county are selected using the same criteria developed to select existing background and Very Intensely Studied Area (VISA) wells. The Florida Department of Health and Rehabilitative Services collects ground water samples from these supply wells and analyzes the samples for approximately 180 parameters. The analyses supplement data generated by the ground water quality monitoring network and supply general water quality data.

5.2.1 Existing Water-Supply Wells

Water-supply wells, which include wells used for domestic, municipal, irrigation, and industrial supply, generally are suited only to monitoring designs that permit the withdrawal of water samples using the existing pumping system. If analytical constraints

[1] This document is in draft form. Further information on this document may be obtained from the EPA Office of Pesticide Programs, Environmental Fate and Effects Division; Telephone: (703) 305-6128.

require the use of special sample collection pumps or equipment, these wells may have to be excluded from the monitoring design unless the pumping system may be bypassed, allowing the sample to be withdrawn directly from the well column. Sampling from water-supply wells in this way, however, is difficult, potentially time consuming, and may inconvenience the well owner.

It is important to remember that the quality of analytical results inherently depends on the quality of the ground water sample withdrawn from a well. Certain aspects of well construction are essential to determine the reliability of an existing well for monitoring purposes. In ideal circumstances, this information may be found in well construction reports maintained by the State offices responsible for ground water protection. The format of well construction reports and the information they contain will vary.

5.2.2 Existing Monitoring Wells

The following criteria were used in **Minnesota's** ground water quality program to select existing wells and springs for inclusion in the monitoring network (Clark and Trippler, 1977):

- Sampling points are uniformly distributed with regard to the regional flow systems;
- Sampling points are selected so that baseline quality as well as areal changes in water quality can be defined;
- If possible, sampling locations or points are part of existing water resource information systems; and
- Sampling points are used frequently to ensure that ground water samples are representative.

Attempts were made in Minnesota to locate at least one sampling point in every 1,000 square miles, or approximately one per county.

Monitoring wells are typically designed to monitor site-specific conditions. For this reason, their well construction characteristics should be ascertained before adopting an existing monitoring well into a regional monitoring network. It is important to collect information on the hydrogeologic setting (ground water flow, direction, rate, and depth to ground water), well construction, placement, and ground water discharge when choosing existing wells as part of a monitoring scheme. Each monitoring well should be evaluated to ensure that representative ground water samples can be collected from the appropriate aquifer. Existing monitoring wells situated upgradient of expected contamination sources may be suitable for use in baseline monitoring networks.

The appropriate design of ground water monitoring wells is dictated by their diameter, depth, perforated interval, and the compatibility of well construction materials with the subsurface environment and chemical analytes. The drilling method selected and the well installation procedures employed also influence the spatial dimensions and the material composition of a ground water monitoring well.

There are five components of a shallow well designed to monitor an unconfined aquifer:

- Screening;
- Riser casing;
- Filter pack;
- Sealing materials; and
- Cement apron and protective casing.

The typical well detail shown in Figure 5-2 does not always apply to every hydrogeologic situation. It is intended as a general guide to design components common in most monitoring well construction. Details on construction techniques for monitoring wells may be found in Aller et al. (1990), Parker et al. (1990), and Nielson and Johnson (1990).

5.2.3 Existing Observation Wells

Observation wells are generally nonpumping wells that are open or screened throughout the thickness of the aquifer. These wells can be constructed to exacting specifications, but are typically designed for temporary installations. Observation wells may be constructed in an available boring drilled to obtain lithologic samples. These wells are most suited to monitor composite water quality or head characteristics in an aquifer. Ground water samples, however, can be collected from these wells to establish qualitative ground water quality conditions. If properly pumped to obtain water samples that are representative of the aquifer, these wells may also yield quantitative information on ground water.

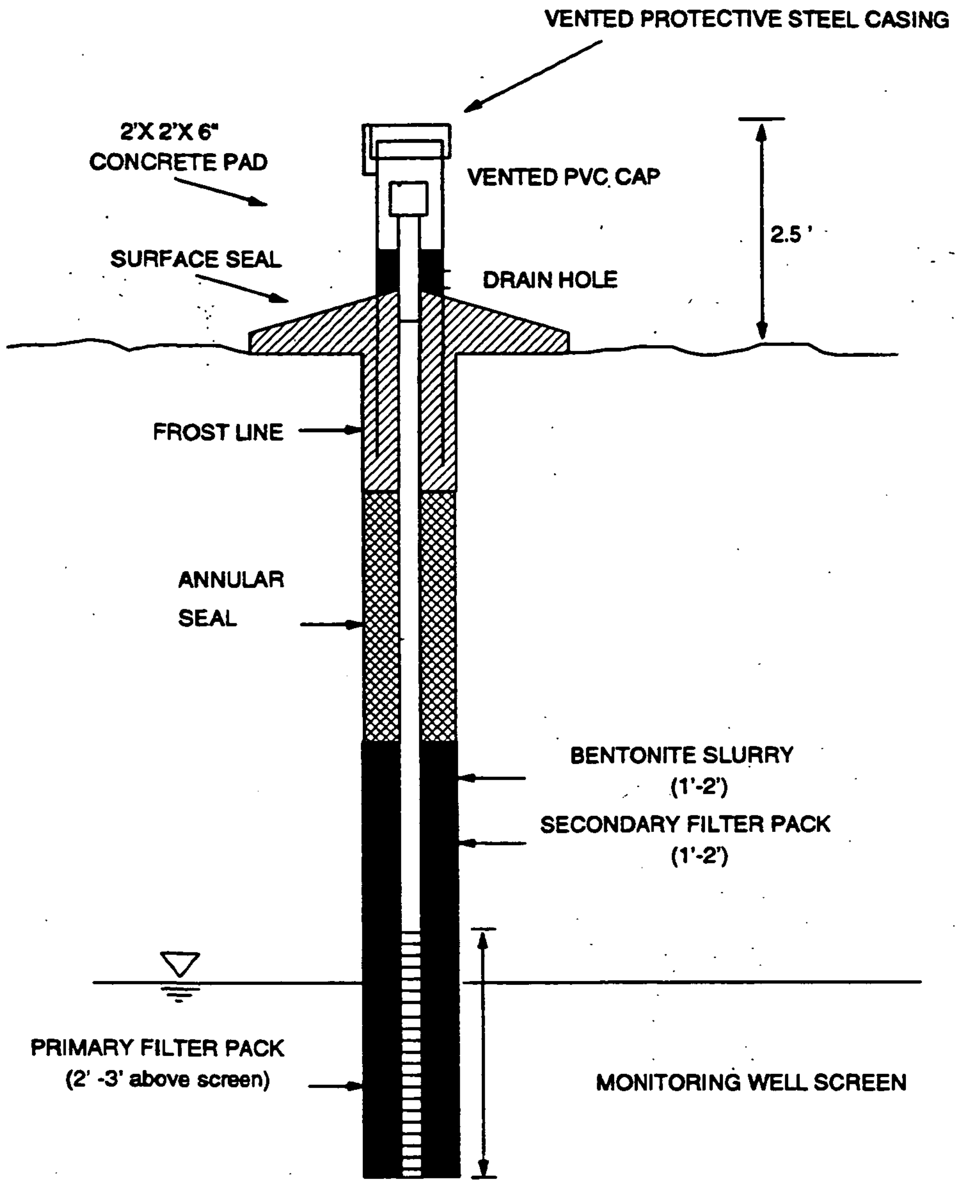
5.2.4 Existing Piezometers

Piezometers are generally small-diameter, nonpumping wells used for the single purpose of measuring hydraulic-head changes in a discrete zone of an aquifer. Screen lengths for piezometers are typically small. Ground water samples are often difficult to obtain from a piezometer and may only represent a discrete aquifer interval.

5.2.5 Development of a New Monitoring Well

Two major factors should be considered in developing new monitoring wells. They are: (1) development techniques and (2) removal of influences from formation of wells. Table 5-1 is intended as a guide to the basic well design components included on most well construction records.

Figure 5-2. Typical Monitoring Well Detail



(NOT TO SCALE)

Table 5-1. Basic Design Components for New Monitoring Wells

Design Components	Description
Well Diameter	• Size allows initial estimate of well casing volume that must be purged to remove stagnant water prior to sample collection.
Casing Material and Screen Information	• Screen length based on aquifer thickness, available drawdown, and nature of the stratification of the aquifer. • Water-supply wells may have multiple screened intervals. Monitoring samples should be collected from discrete sections of an aquifer. • Casing and screening material and the method by which they are installed can impact the quality of ground water samples.
Filter Pack	• The filter pack zone separates the screen from the formation material, increasing the effective hydraulic diameter of the well. • Filter pack material (e.g., gravel pack, sand pack) depends primarily on the textural characteristics of the aquifer formation. • The filter pack sometimes extends several feet above the top of the screen and consequently may bridge a more impermeable zone in the aquifer. • When the filter pack interval is known, the sample interval is known.
Annular and Surface Seals	• Well seals are designed to prevent surface water from moving down the annulus between the casing and borehole walls. • Wells should be designed to provide continuous sanitary protection. • Wells covered by an enclosure still require a surface seal. • A frost sleeve should be installed around casings in areas that experience average winter temperatures below freezing. If a frost sleeve is absent in colder areas, the structural integrity should be assessed. • A well seal is designed with respect to the mean water table and the compatibility of the sealing clay species with the geologic environment. • Sealing material volume in the annular space and methods used to emplace sealing material may influence seal integrity. • Surface seals or aprons (of sufficient size with sloping surfaces) should be constructed of concrete, not cement.

1. *Development Techniques*

Appropriate well development techniques vary from well to well. Often a variety of techniques are used to achieve the desired results. Commonly used development methods for monitoring wells include overpumping, backwashing, surging, bailing/surging, jetting, airlift pumping, and air surging. These are described by Aller et al. (1990).

2. *Removal of Influences*

During final development of a monitoring well, influences from the drilling process should be removed from the formation. Extensive time and effort are generally required to restore "natural" flow into the well from the formation. It is most important that the ground water withdrawn from the well be representative of the indigenous aquifer conditions. Some coarse sedimentary aquifers and fractured rock aquifers are naturally turbid and require less extensive development. Most unconsolidated formations, however, are not turbid and development for the majority of aquifers should continue until the ground water withdrawn from the well is clear and free of sediment.

5.2.6 Special Considerations for Ground Water Monitoring in Karst Terrains

Approximately 20 percent of the soils in the United States developed over soluble carbonate type rocks, such as limestone and dolomites. Surface and subsurface features in these areas are markedly different from those in areas underlain by other rock types. In carbonate terrains, surface depressions develop where soluble material in the underlying bedrock was removed by solution, causing the overlying surficial material to collapse into the cavity beneath. These depressions, called sinks, are generally oval or oblong in shape and when they coalesce, elongated solution valleys form. The term ***karst topography*** is used to describe these areas of sink holes, caves, and streamless valleys. As a generalization, almost any terrain underlain by near-surface carbonate rock is some type or stage of karst topography.

In karst aquifers that have a well-integrated conduit system, pollutant and ground water flow is analogous to flow in surface stream networks. Monitoring networks in karst terrain typically utilize a combination of springs and monitoring points along cave streams. Using dye-tracing techniques to define karst drainage patterns is the most reliable strategy for selecting monitoring points (Quinlan and Ewers, 1986). Flow in karst aquifers may be turbulent and may occur along discrete conduits that converge and terminate as springs. The ground water quality of a spring may therefore be representative of the mean of the flow system. Wells can sometimes also be used to intercept and monitor the conduits draining a ground water basin.

As outlined by Quinlan and Ewers (1986), design of a ground water monitoring network in karst areas should include:

- Locating springs, streams in sinkhole bottoms, and major streams in caves;

- Preparing potentiometric surface maps;
- Dye-tracing under base flow and high flow conditions to establish connections between an area, nearby springs, and underground streams;
- Monitoring hydrogeologically connected points; and
- Monitoring at least one nearby geochemically similar spring shown by dye-tracing not connected to the site, for determining background.

Sampling frequency should be based on hydrograph records of spring flow. Studies have shown that complex and widely differing variations in analyte concentrations occur in relation to storm events (Hallberg et al., 1985). Guidance for EPA-recommended protocols for ground water monitoring in karst terrains is addressed further by Quinlan (1989).

5.2.7 Special Considerations for Monitoring in Fractured Rock Terrains

Many scenarios of anthropogenic waste isolation include burial in unconsolidated near-surface deposits; these wastes, however, can leach into the underlying bedrock. Fractures in the bedrock have the capacity to transport contaminants rapidly over large distances, and therefore, can have a great effect on ground water and surface water resources. Prediction of fluid movement and chemical transport in fractured rock is a complex task because of the difficulty in physically identifying and mathematically characterizing the spatial variability of hydraulic properties of bedrock over various length dimensions. This problem is encountered in all subsurface flow regimes, but it is more acute in fractured rock because of extreme spatial variability and abrupt spatial changes in hydraulic properties. These conditions make it difficult to design field experiments and to employ interpretive methods of predicting fluid movement and chemical transport developed for application to unconsolidated porous media.

5.3 Monitoring Protocols

This document addresses four common ground water monitoring approaches:

- Baseline;
- Problem identification;
- Response; and
- Evaluation.

Baseline monitoring and evaluation monitoring systems are typically used to extrapolate information from individual monitoring points to regional ground water quality conditions. Problem identification and response monitoring systems typically focus on smaller geographic areas or on particular ground water quality problems. The following

The basic design elements **Texas'** State Plan for Monitoring the Presence of Agricultural Chemicals in Ground Water depend on exchanging information between State, federal, and agricultural groups, as well as associated organizations involved with the management and use of pesticides. The Texas Natural Resources Conservation Commission (TNRCC) is the lead agency for ground water monitoring associated with the presence of agricultural chemicals.

The TNRCC used aquifer sensitivity assessments to characterize aquifer sensitivity. The TNRCC maintains eight data bases covering pesticide-use characteristics, water quality, temporal variations in water quality, irrigation, land use, soil properties, cropping patterns, and aquifer sensitivity. The information from the data bases is combined using a GIS to spatially relate specific parameters and predict areas where aquifers are vulnerable to contamination from particular agricultural chemicals.

The monitoring well network in Texas consists of 8,000 existing observation wells that are supplemented with approximately 150,000 identified private water-supply wells. The Texas Water Development Board maintains the 8,000 observation wells, performs spring inventories, and establishes ground water budgets. Ground water levels are monitored at least once per year. Ground water samples are also collected, in an effort to establish baseline ground water quality and identify potential contamination problems. These samples are analyzed for indicator parameters including bacteria, volatile organic compounds, arsenic, and nitrates. The observation wells are also sampled and analyzed for agricultural chemicals on three- or four-year cycles.

The TNRCC performs problem identification monitoring to substantiate suspected contamination problems. The TNRCC collects water samples from private water-supply wells to screen for a particular agricultural chemical, when requested by EPA, or when observations by private citizens or organizations indicate the need for monitoring at a specific site.

If concentrations of an indicator parameter or pesticide are elevated, the contamination is confirmed by resampling the affected wells. A reconnaissance of the area around each affected well is conducted to identify possible contamination sources and nearby wells are monitored to assist in identifying the contamination source. When contamination may be attributed to a point source, the Texas State Soil and Water Conservation Board and various agricultural groups develop a set of voluntary pesticide handling practices.

Texas may also initiate the following options when a point source is identified: requiring permits for the use of the agricultural chemical; continued monitoring; legal enforcement; public education; and/or remediation.

When contamination is detected from a nonpoint source, the State may initiate the one or more of the following response actions: reevaluation of hydrogeologic data; continued monitoring; education of product users; development of chemical-specific plans; modification of the product label; enforcement of existing Texas Water Codes; and/or use restrictions based on site-specific conditions.

The Texas observation well network is monitored annually to evaluate the effectiveness of management practices relating to identified nonpoint and point sources of contamination.

Contact: Texas Natural Resources Conservation Commission, P.O. Box 13087, Capitol Station, Austin, Texas 78711-3087; Telephone (512) 239-1000.

sections provide information on the development of monitoring plans for these four monitoring designs.

5.3.1 Baseline Monitoring

Baseline monitoring measures ground water quality and compares it to known background water quality standards. The background quality of the ground water in a given aquifer is determined prior to the onset of activities that may alter the water quality. Continued monitoring establishing trends in time or space, or both, may then continue. Baseline monitoring designs commonly use existing wells, which are incorporated into the overall design of a regional ground water monitoring system. This type of monitoring is useful to determine baseline water quality conditions, to identify the existence of a ground water contamination problem, to assess impacts of land and water use, and to plan policies and regulations.

Table 5-2 presents examples of baseline monitoring programs and data bases from a number of States. The table highlights baseline studies of rural drinking water in Iowa and Ohio, public and private water supplies in Minnesota, and water quality in aldicarb-use areas in Florida. In addition, the table presents information on California's Pesticides in Ground Water data base. Contact addresses of the sponsoring agencies are also provided.

Costs of a baseline monitoring program are dependent upon the number of wells sampled, the sample frequency, and sampling and data analysis requirements. Considering the State ground water protection goals and targeting sensitive aquifers may further focus the objectives of a baseline monitoring program. For example, Sanders et al. (1983) states that because confined aquifers are less subject to surface contamination, the water quality of these aquifers is likely to change more slowly than that of shallow unconfined aquifers. For this reason, confined aquifers could be sampled less frequently than shallow aquifers without compromising the monitoring designs. Thus, in balancing costs versus information gained from targeted aquifers, variable sampling schedules can sometimes be justified and may enable the expansion of the areal coverage of a sampling network.

Design of Baseline Monitoring Networks

Baseline monitoring networks are typically regional or Statewide in scale. States considering the use of State-wide baseline monitoring should be aware of the limitations in using this approach to forecast over a wide area. Further, States may find it more cost-effective to target baseline monitoring on the basis of aquifer sensitivity, ground water vulnerability, or other priority ground water areas. Several approaches may be used to design ambient ground water monitoring networks (Nacht, 1983). Canter et al. (1987) outlined three basic steps for the design and operation of a baseline monitoring network: (1) determine which existing wells should be included in the network; (2) determine whether new monitoring wells are needed, and if so, where they should be located; and (3) document data needed for handling, storage, retrieval, and reporting

Table 5-2. Examples of Baseline Monitoring Programs and Data Bases

State/Title	Agency	Contact Address	Description
Iowa "State-Wide Rural Drinking Water Survey"	Department of Natural Resources, Geological Survey Bureau	109 Trow Bridge Hall Iowa City, Iowa 52242-1319 (319) 335-1585	Designed to characterize all rural drinking water wells in Iowa with emphasis on key pesticides used in the State.
Minnesota	Department of Agriculture Agronomy Services Division	90 West Plato Boulevard St. Paul, Minnesota 55107 (612) 297-3994	Large-scale Statewide survey that targeted public, private, observation, and irrigation wells.
	Department of Health Environmental Health Division	925 Delaware Street, S.E. Minneapolis, Minnesota 55459 (612) 627-5170 (public wells) (612) 627-5147 (private wells)	
California "Pesticides in Ground Water Data Base"	California Environmental Protection Agency Department of Pesticide Regulation	1220 N Street Sacramento, California 95814 (916) 324-4188	Compendium of existing studies on what is in California's ground water and where it is. Provides information on a number of site-specific studies of ground water quality.
Florida	Department of Environmental Protection, Bureau of Drinking Water and Ground Water Resources	2600 Blair Stone Road Tallahassee, Florida 32399-2400 Telephone: (904) 488-3601	Two-phase, EPA-sponsored study of aldicarb in public wells. Phase I focused on all aldicarb use areas. Phase II focused on heaviest use areas. Found no aldicarb in deep public wells. Determined aldicarb did not impact deep, protected public drinking water wells in Florida.
Ohio	Department of Agriculture	8995 East Main Street Reynoldsburg, Ohio 43068 Telephone: (614) 866-6361	Surface and ground water State-wide study similar to the Iowa study noted above. Focuses on drinking water sources.

Florida's monitoring strategy utilizes a monitoring well network established in the mid-1980s. One component of the Florida monitoring strategy is the background water quality network. This network assesses the general ground water quality of the region, independent of known contaminated areas. It consists of approximately 1,700 monitoring points that include existing wells, newly constructed monitoring wells, and protected springs. Chemical, microbiological, and radiological analyses are combined with available historical data to estimate baseline ground water quality. Areas where ground water contamination has been identified are excluded from this network.

Florida monitors its ground water well network quarterly. A smaller representative segment of the network is monitored monthly for indicator parameters to determine changes in ground water quality over time. As summarized by Florida's Department of Environmental Regulation, the background network was developed in the following phases:

- Phase I: Data collection and compilation, and location of existing wells that could be incorporated into the network;
- Phase II: Selection and drilling of initial monitoring wells;
- Phase III: Initial sampling of the background network to determine ground-water quality trends and define baseline conditions;
- Phase IV: Resampling of wells found to contain significant concentrations of one or more parameters;
- Phase V: Refinement of the network through removal of redundant wells and affected wells and drilling of additional wells where needed; and
- Phase VI: Ongoing periodic resampling to define variations in ground water quality over time.

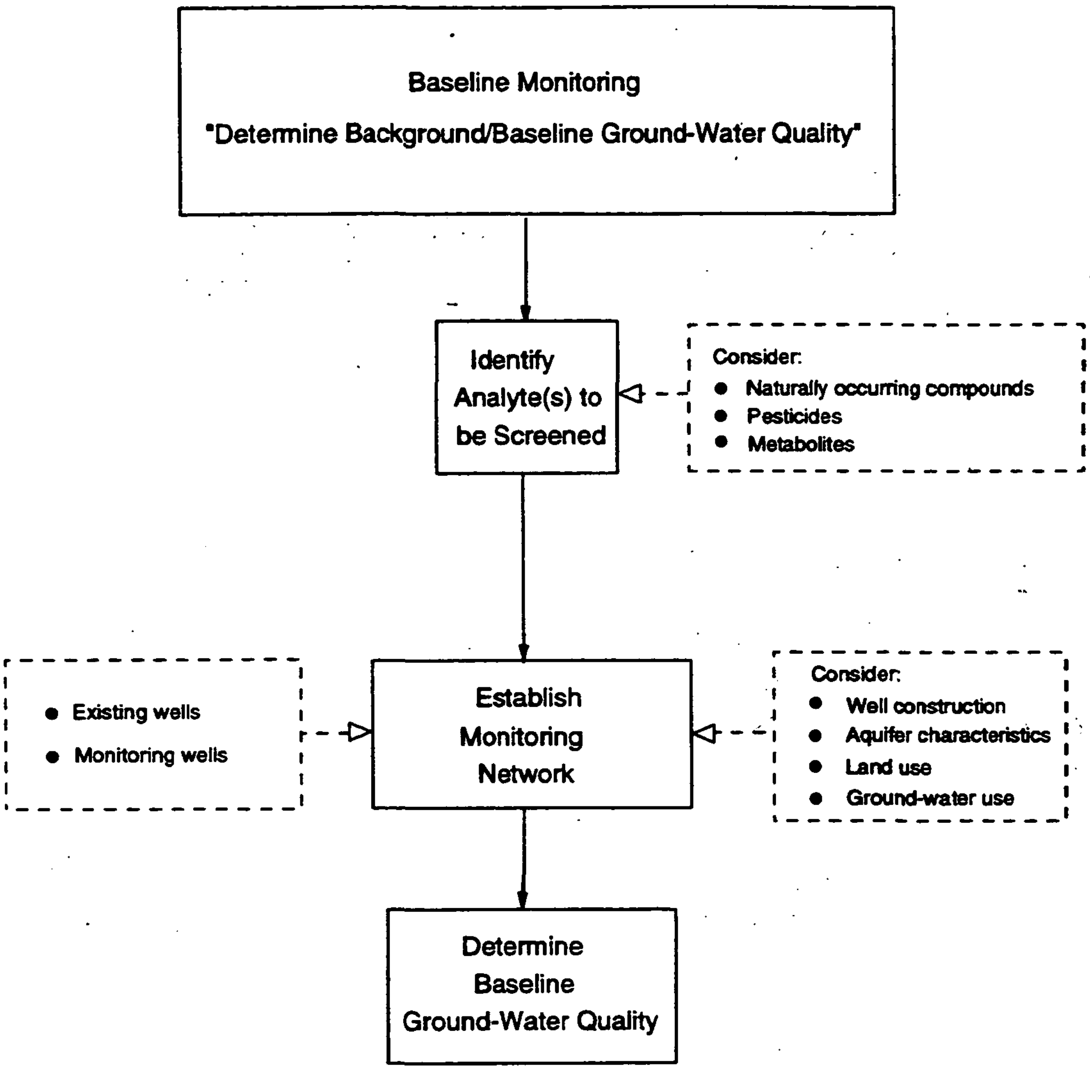
mechanisms. The general steps for the design and operation of a baseline monitoring project are shown in Figure 5-3.

Where existing wells are not adequate to meet the spatial needs of a baseline network, some new wells may have to be installed. In some cases, new wells may be needed to fill in spatial gaps or to define shallow aquifer conditions as a prelude to what might be found in deeper aquifers. For economic reasons, it is desirable to keep the installation of new wells to a minimum. Canter et al. (1987) report that the probability existing wells will meet satisfactorily the needs of a baseline monitoring network decreases as the basin size under investigation increases.

Statistical Considerations and Data Analysis

The statistical selection of sampling sites is normally guided by a prespecified random process. The two types of experimental design for sample selection are simple random sampling and stratified random sampling. The information collected from these sampling sites is normally used to make inferences about the target population. Cohen et al. (1986) state that the statistical conclusions drawn from such an investigation cannot be applied reliably to changes outside of the target population. Likewise, if wells are

Figure 5-3. Baseline Monitoring



Baseline monitoring conducted by the **Minnesota** Department of Health and Agriculture in the 1980's relied on the following factors:

- Pesticides were included on the basis of information on toxicology, environmental transport and fate, and common use in the State;
- Wells were selected in agricultural regions of the State, and within those regions where local or regional soils and hydrogeological conditions made the ground water especially sensitive. Wells were also chosen to provide areal coverage of the State's agricultural regions and cropping patterns; and
- About 100 drinking water wells, irrigation wells, and observation wells, five drain tiles and 400 public drinking water wells were sampled. Each was sampled on a time-series basis. (Klaseus, Buzicky, and Schneider, 1988).

arbitrarily included or excluded from sampling at later stages of the monitoring, the study's statistical validity may suffer significantly.

Simple random sampling is mostly suited to narrowly designed and homogeneous areas. The major disadvantage of simple random sampling is that it does not utilize the relevant information available about the environment such as pesticides leaching to ground water (Cohen et al., 1986). Such information, however, is fully utilized in a stratified random sampling approach. The size of a stratified random sample depends upon many factors such as the population of each stratum, the degree of precision desired for estimates, the variance of the estimate, and the cost of obtaining a sample in each stratum (LeMasters and Doyle, 1989). Cochran (1967) and Cohen et al. (1986) identify three major advantages of a stratified random sampling approach. These include: (1) the possibility of significantly lower variance for the subpopulation estimates; (2) the ability to obtain population estimates for certain subdivisions of a target population; and (3) elimination of the possibility that certain segments of the population may not be sampled. Detailed information regarding the use of these sampling methods to determine the sample size is given by Scheaffer et al. (1979).

Stratified sampling should only be used, however, when certain conditions are satisfied. It may otherwise limit the usefulness of results. The National Survey of Pesticides in Drinking Water Wells sought to identify areas of the country where drinking water wells were most likely to contain pesticides and to oversample these areas. Stratification was based on county-level surrogates for pesticide use and ground water vulnerability (county-level DRASTIC measures). The Survey's Phase II results indicate that county-level stratification was ineffective. The Phase II Report lists three suggestions for improvements:

One of the components of **Florida**'s monitoring strategy is referred to as the Very Intensely Studied Area (VISA) Network. Florida's Department of Environmental Protection adopted this problem identification type of monitoring to monitor areas highly susceptible to ground water contamination. Florida identifies a VISA based on hydrogeology and land-use information. Analytical data from VISA wells are statistically compared to like parameters sampled from background network wells which are representative of the same segment of an aquifer. In this way the effects of land-use practices on ground water quality are determined. The data analysis is used to make reasonable predictions of the effects of similar land uses in hydrogeologically similar areas. The development of the VISA Network resulted following phases:

- Phase I: Evaluation of data to determine areas of predominant land use;
- Phase II: Determination of relative susceptibility to contamination of each potable aquifer;
- Phase III: Determination of percentage of each aquifer used as a source of potable water;
- Phase IV: Selection of VISAs based on above data;
- Phase V: Data collection and compilation, and selection of suitable existing wells within each VISA;
- Phase VI: Drilling of additional wells as needed; and
- Phase VII: Sampling of VISA wells.

- Oversample strata only if the criteria used for stratification can be measured with sufficient accuracy to improve the survey estimates and precision. The predictive power of the stratification variables must be known to be high;

- Stratify by pesticide use only if a good local measure of such use is available; and

- Ensure that data used for stratification include accurate data about wells/ground water vulnerability.

5.3.2 Problem Identification Monitoring

Problem identification monitoring is monitoring to identify contamination problems in the areas where problems are most likely to occur. The objectives are to uncover potential pollution problems as early as possible by relating contamination levels to the composition, quantity, and quality of a pollutant, thereby providing a basis for preventive or corrective actions. This type of monitoring is often less costly than ambient monitoring, since it concentrates on identifying sensitive areas and important sources of pollutants for targeted monitoring.

Aquifer sensitivity, pesticide use, agricultural practices, and current or potential ground water use and value are considerations in designing a problem identification monitoring network. Problem identification monitoring for pesticides should assess

The **State of California**'s problem identification monitoring program was used in combination with evaluation monitoring. The California Department of Pesticide Regulation established Pesticide Management Zones (PMZs) in areas where a pesticide was detected in ground water or soil and contamination is attributable to legal agricultural use. Each PMZ is pesticide-specific. The five different types are ground water monitoring are described below.

- Monitoring is conducted in the four geographical sections surrounding the area where a pesticide has been detected in ground water. The purpose is to determine whether the residues resulted from legal agricultural use or from some other source. If the source was a legal agricultural use, the residue falls within the scope of the Ground Water Protection Program. If it is an illegal use, it falls within the Pesticide Enforcement Program. If the residue is attributable to some other source, it falls under the jurisdiction of the State Water Resources Control Board.

- Monitoring in sections adjacent to PMZs is conducted to determine whether existing PMZs should be expanded. The purpose of this type of monitoring is to determine the extent of contamination.

- Subsequently, effectiveness monitoring is conducted to determine whether use modifications for known leachers prevents downward movement to ground water.

- Next, compliance monitoring is conducted to determine whether a known leacher that has been banned in some or all PMZ sites is still used in these sites.

- Finally, legislatively mandated lists of pesticides which have the potential to leach but that have not yet been found in ground water are monitored. Ground water protection list monitoring is conducted to determine whether residues of suspected leachers occur in ground water or soil under certain conditions.

Contact: California Department of Pesticide Regulation, 1020 N Street, Sacramento, California 95814.

whether or not a targeted pesticide has contaminated ground water. A comprehensive discussion of the design, implementation, and statistical analysis of problem identification or "hot spot" monitoring is presented by Gilbert (1987).

In some instances, previously collected monitoring data or aquifer sensitivity/ vulnerability assessments may indicate the potential for ground water pollution in certain areas. States can use this information to identify likely "hot spots" for problem-identification monitoring. Combining GIS with screening models (Chapter 3) is valuable in identifying potentially vulnerable areas and maintaining problem identification monitoring data bases. States can use these tools to identify susceptible locations that warrant more detailed evaluations of water-quality changes over time.

Other triggers for problem identification monitoring include (1) a change in agricultural practices such as new cropping practices, the use of new compounds, or new uses of existing compounds; (2) development of health concerns or new toxicologic findings or epidemiologic evidence; and (3) identification of assessment techniques such as previous monitoring or modeling efforts that identify areas having a vulnerable aquifer.

Table 5-3 presents examples of problem identification monitoring programs conducted by a number of States. In Wisconsin, for example, widespread monitoring assesses nonpoint source and point source contamination. For further information on these studies contact the agencies listed in Table 5-3.

The **Wisconsin** Department of Agriculture, Trade, and Consumer Protection began a ground water monitoring program in 1985. In 1988, the State adopted health-based ground water standards for atrazine and alachlor. Although the monitoring program indicated those chemicals could reach ground water at levels above the standards in susceptible areas, no reliable information was available on the Statewide extent of the presence of these chemicals in ground water. The State used a stratified random sample of 534 wells on Grade A dairy farms and obtained water samples between 1988 and 1989. The State used milk producers for several reasons. Funding limitations required a readily available list to be used because milk producers are part of an ongoing inspection program, the list of Grade A producers is complete and is updated regularly. Because dairy farms are geographically distributed, results are probably representative of variations in soil, climate, and hydrogeology in the State.

Follow-up in the Wisconsin Grade A Dairy Farm Survey included resampling when pesticides were detected above State enforcement standards, further analysis of milk from the farm, follow-up interviews about pesticide use and handling, interviews about construction of the sampled well, collection of soil samples in pesticide mixing and loading areas, collection of information about commercial applications, and collection of information on pesticide disposal practices.

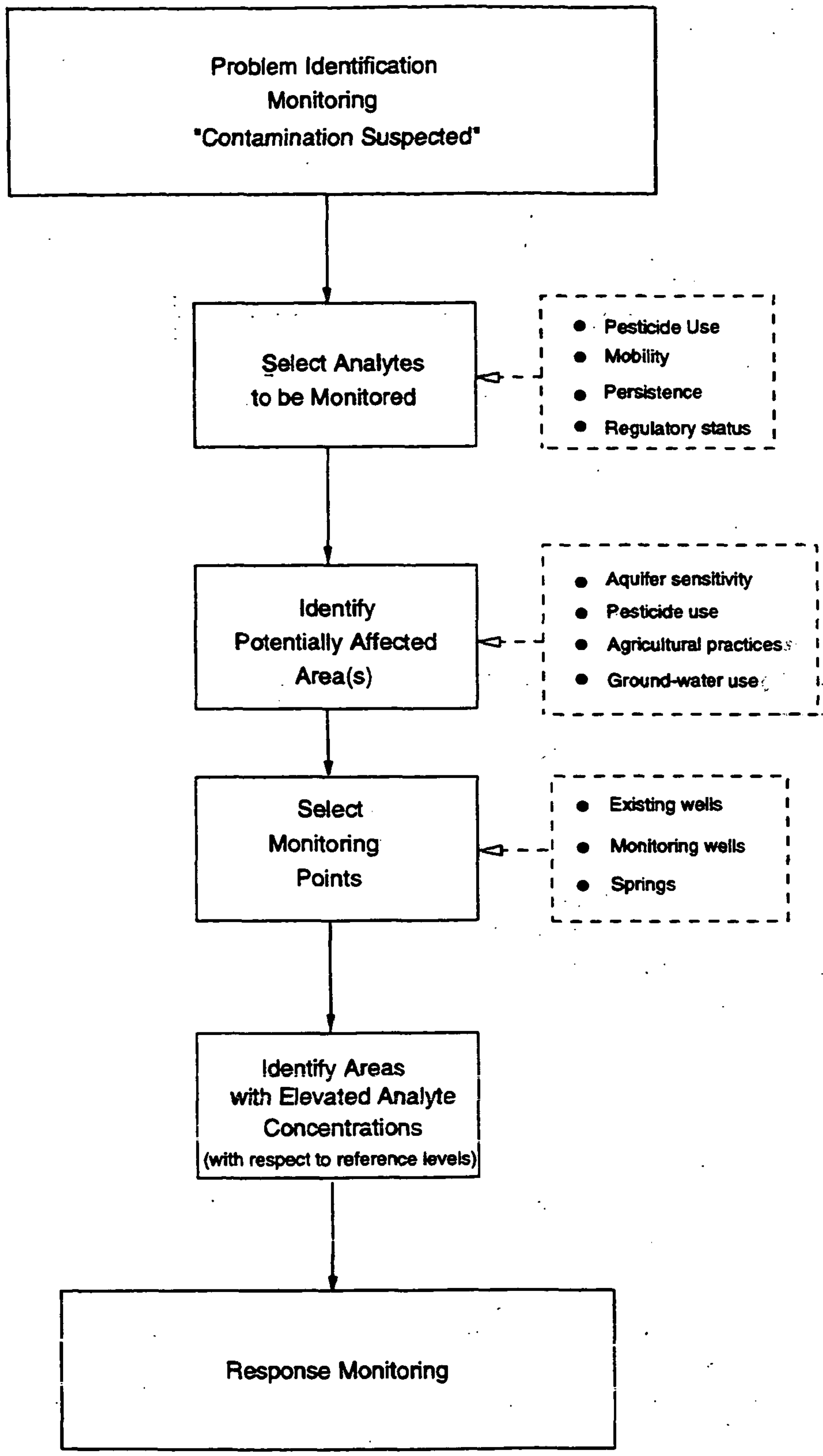
Design of Problem Identification Monitoring Networks

Problem identification monitoring networks are typically local or countywide. Many of the general considerations outlined in Section 5.3.1 for baseline monitoring network design are also applicable to problem identification monitoring systems. The development of problem identification monitoring networks for ground water monitoring programs is divided into two phases: (1) the selection of the parameters (pesticides); and (2) the selection of site(s). Figure 5-4 depicts the steps in the development of a problem identification monitoring network.

Table 5-3. Examples of Problem Identification Monitoring Studies

State	Agency	Contact Address	Description
Wisconsin	Department of Natural Resources and Water Resources Management	101 South Webster Street P.O. Box 7921 Madison, Wisconsin 53707 (608) 267-7610	Field monitoring to assess both point source and nonpoint source contamination.
New York	Department of Health, Ground Water Section	225 Rabro Drive East Hauppauge, New York 11788 (516) 853-3193	Determination of impacts on ground water of chlorothalonil and dacthal use on turf in Suffolk County.
Connecticut	U.S. Geological Survey, Water Resources Division	525 Ribicoff Federal Building 450 Main Street Hartford, Connecticut 06103 Telephone: (203) 240-3060	Research to detect atrazine in monitoring network, as well as some land-use pesticides.

Figure 5-4. Problem Identification Monitoring



Problem identification monitoring may include the use of questionnaires to obtain data about pesticide use in the area of detections and pesticide handling, mixing, and disposal practices. Such data may assist in identifying point-source problems and distinguishing situations in which the presence of pesticides in ground water is due to mishandling or improper disposal. The National Survey of Pesticides in Drinking Water Wells, for example, collected useful information related to pesticide contamination of wells using questionnaires administered to homeowners, renters, well operators, and agricultural extension agents. Data collected by telephone also worked effectively. The Pesticide Survey results indicate, however, that respondents do not always provide accurate data on key factors associated with the presence of pesticides or nitrates in drinking water wells such as pesticide use, spills, and disposal. States planning to use questionnaire data should recognize that some respondents will not be able or do not wish to recall using the pesticide. Likewise some respondents may remember only a generic type of pesticide (e.g., crab grass killer) for which it is impossible to determine the active ingredient unless they have kept the container.

5.3.3 Response Monitoring

Response monitoring is typically triggered by detections of pesticides in ground water at levels near or above a reference level (Chapter 6). Figure 5-5 depicts considerations in the design and implementation of a response monitoring network. Response monitoring is mainly concerned with determining the nature, quantity and source of ground water contamination in an area where a problem exists. This type of monitoring is usually done to evaluate the extent of a previously identified contamination problem or to gather evidence for enforcement by State or Federal agencies.

Unlike baseline monitoring, existing wells will likely not be in proper locations or have the proper characteristics for inclusion in a response monitoring network. Response monitoring components include sampling other wells near the well where pesticides are discovered and installing monitoring wells to determine whether contamination is a result of routine field application of a pesticide. Events that may trigger response monitoring include:

- Pesticide detection at any level;
- Pesticide detection at or above a specified action level; and
- Qualitative detection such as field immunoassay tests or other environmental indicators which suggest pesticide contamination.

A discussion of response monitoring triggers is included in Chapter 6. Examples of response monitoring programs in New York and Florida are presented in Table 5-4.

5.3.4 Evaluation Monitoring

Evaluation monitoring should be conducted to assess impacts of prevention or response measures on ground water quality. Evaluation monitoring is typically conducted at a regional, county, or subcounty scale. Components evaluated may include proposed

Figure 5-5. Response Monitoring

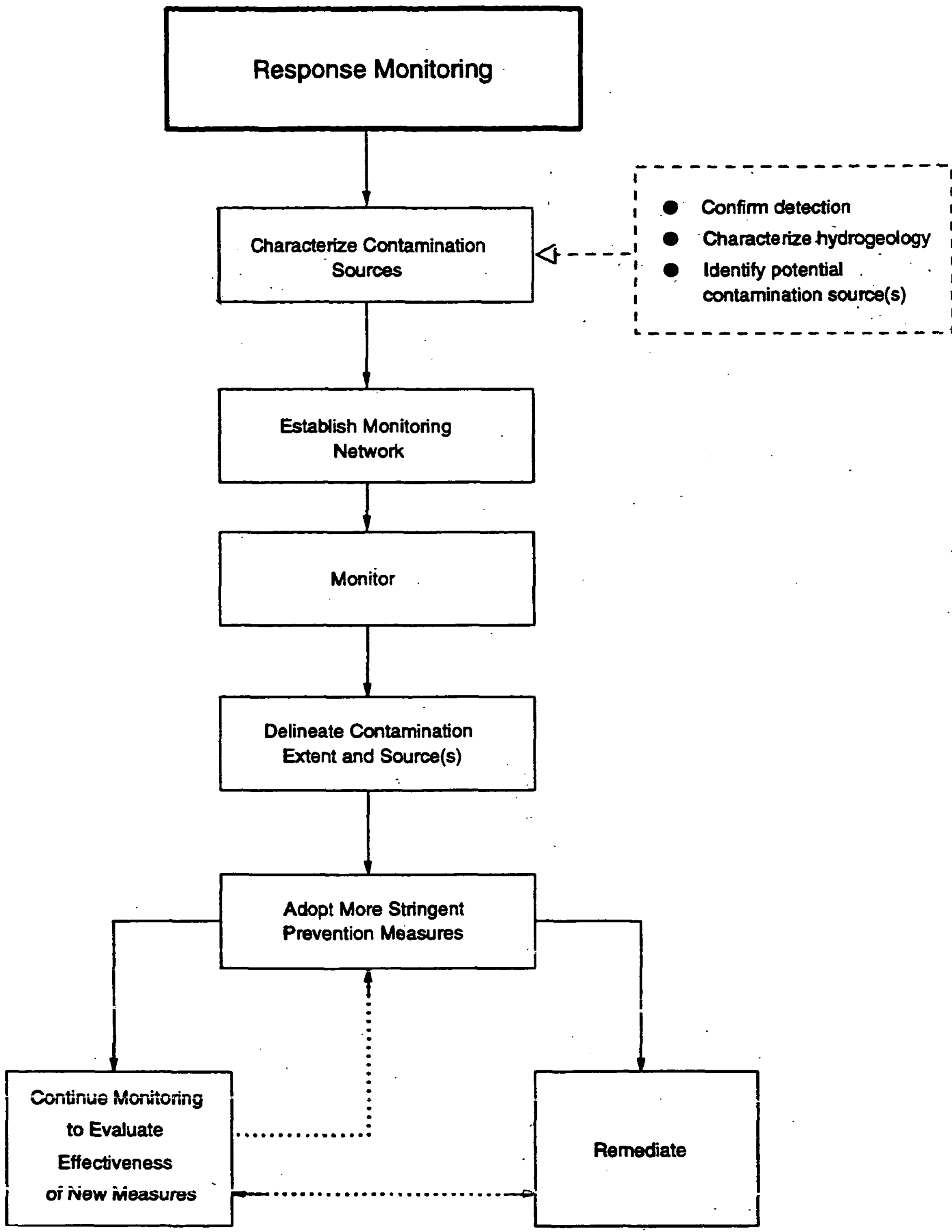


Table 5-4. Examples of Response Monitoring Studies

State	Agency	Contact Address	Description
New York	Suffolk County Health Department	Ground Water Section 225 Rabro Drive East Hauppauge, New York 11788 (516) 853-3193	Large-scale survey to determine extent of aldicarb contamination in drinking water in response to confirmed detections.
Florida	Department of Agriculture and Conservation Services	Capital Plaza Level 10 Tallahassee, Florida 32399-0810	Investigation of detections of aldicarb in drinking water at a fernery site. Included the sampling of approximately 40 drinking water wells in known areas of aldicarb use and the installation and monitoring of several monitoring wells. The investigation also evaluated the installation and testing of new drinking water wells.

or existing Best Management Practices (BMPs) and regulations. Evaluation monitoring is conducted mainly to ascertain: (1) the effectiveness of BMPs, and (2) to demonstrate the effectiveness of BMPs or remedial actions on ground water quality. The components of an evaluation monitoring program are depicted in Figure 5-6.

Particular emphasis should be placed on defining evaluation criteria and specifying how monitoring results will be judged (i.e., what constitutes success or failure). Other monitoring approaches discussed in this chapter, particularly baseline monitoring and problem identification monitoring, can provide data assessing the impact of prevention or response measures, provided that these monitoring systems are designed to supply all the information essential for such evaluation. Examples of evaluation monitoring programs in Wisconsin and Florida are highlighted in Table 5-5.

Since it typically takes several years to document the effectiveness of management practices, continued monitoring is necessary. Cumulative effectiveness monitoring can be performed to evaluate the impact of multiple BMPs in achieving short-term and/or long-term management standards. An example is the assessment of the impact of no-tillage, filter strips, grassed waterways, and integrated pest management on the quality of underlying ground water, rather than the specific effectiveness of each BMP separately. Long-term feedback from evaluation monitoring is used to adjust management practices, guidelines, and/or management objectives.

5.4 Quality Assurance/Quality Control

The quality of the information from any monitoring program is directly dependent upon an organization's quality assurance and quality control program. Quality assurance (QA) is a management function which assures that the quality of each component of a monitoring program from planning to final report generation is known and meets quality standards with a stated level of confidence. Quality control (QC) includes those activities that determine and measure quality and determine whether products and results meet specifications and established standards. In the case of monitoring programs, standards address such factors as precision, accuracy, representativeness, completeness, and comparability. QA ensures that the QC function is performed as specified.

There are differing views concerning what constitutes an adequate QA/QC program. Adequacy varies with regulations and EPA programs. Under FIFRA, data submitted to EPA in conjunction with a research, marketing, or use permit must be collected under good laboratory practices (GLPs; see 40 CFR 160). Good laboratory practices cover all aspects of data collection activities. A responsible person or unit is generally assigned to ensure QA activities including good laboratory practices. States that generate data for submission to EPA to register a pesticide or obtain a use permit or an exemption, are required to establish a QA program following good laboratory practices.

Laboratories generating data under the Safe Drinking Water Act are familiar with QA/QC requirements of the Laboratory Certification Program. Other laboratories follow the example of Superfund's Contract Laboratory Program in operating their QC

Figure 5-6. Evaluation Monitoring

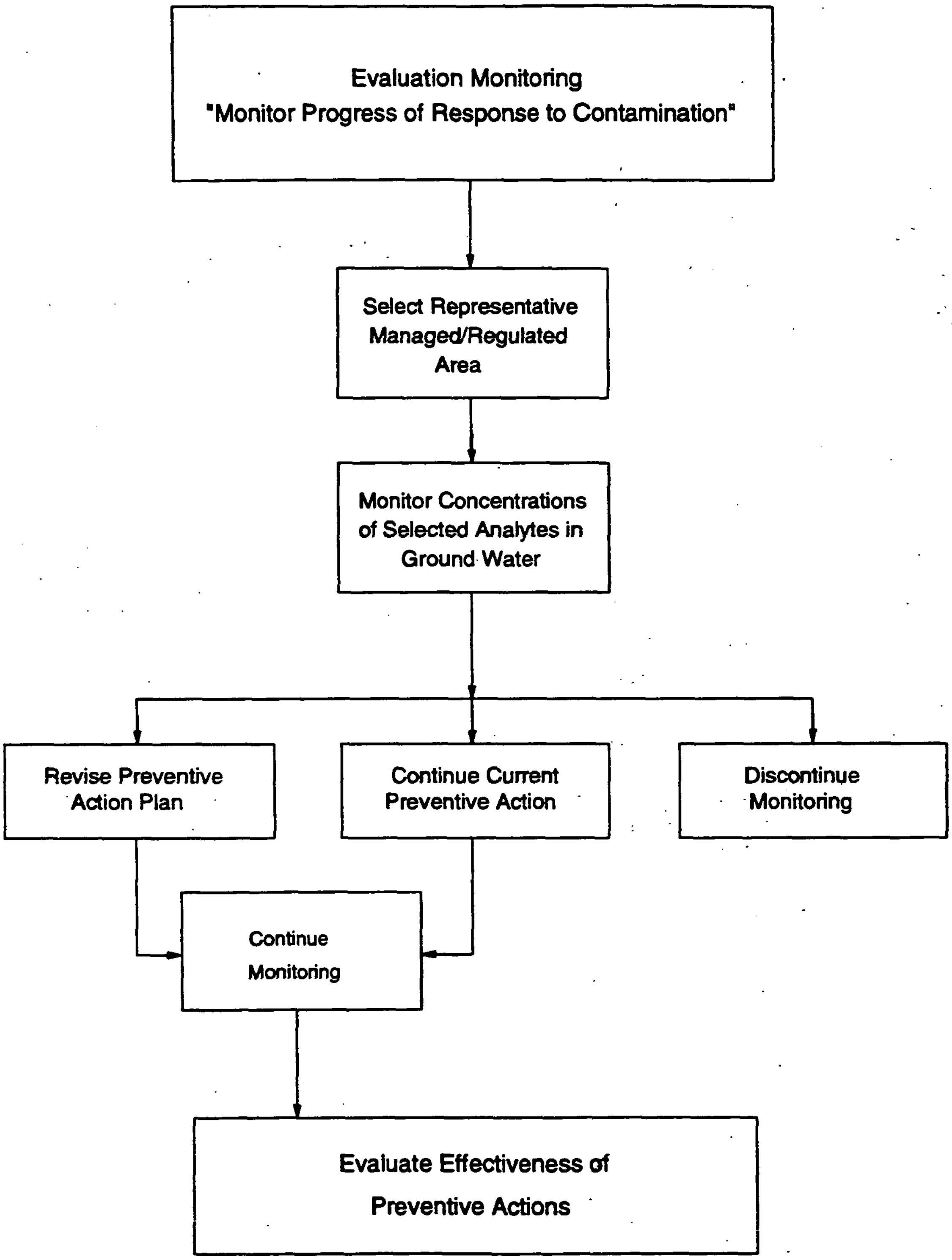


Table 5-5. Examples of Evaluation Monitoring Studies

State	Agency	Contact Address	Description
Wisconsin	Department of Natural Resources, Water Resources Management	101 South Webster P.O. Box 7921 Madison, Wisconsin 53707 (608) 267-7610	Test of early 1980's program for aldicarb, which included lower application rates, use allowed only every other year, and temporary bans on use near wells found positive above 10 ppb. Ten field sites were established in key use counties. Aldicarb residues were found to persist in ground water over the course of the 2-3 year study.
Florida	Department of Agriculture and Conservation Services	3125 Conner Boulevard Capital Plaza Level 10 Tallahassee, Florida 32399-0810	Ongoing monitoring program to ensure that Florida restrictions on aldicarb use are fully protective of drinking-water wells. Program includes well setbacks, reduced application rates, and registration requirements for all users. Approximately 40-50 private drinking water wells located near registered aldicarb users are periodically sampled in each county where aldicarb is applied.

programs. Organizations obtaining federal grants submit QA Program Plans and/or QA Project Plans (QAPPs) as required by 40 CFR 30.503. These Plans are reviewed by different EPA regions and programs using their own acceptance criteria. The guidance specified in 40 CFR Part 30 on the preparation of these documents has been modified by different offices within EPA for their own programs. For instance, the Office of Toxic Substances, Exposure Evaluation Division, has developed guidance for contractors who submit plans to this office. This guidance emphasizes issues in statistical study design. Section 5.4 describes the QA/QC approach for State Monitoring Plans.

In a Generic SMP, the QA program and its policies, organization, procedures, and systems are described. A QAPP is only necessary for a Pesticide SMP. States obtaining an EPA grant or who are familiar with the Agency's granting requirements can use the QA Program Plan guidance for a Generic SMP and the QAPP guidance for a Pesticide SMP to reduce the amount of time required to generate this material. The items addressed in QA/QC plans are discussed in the following sections. The level of detail in these plans should be proportional to the cost and significance of the monitoring efforts they address.

5.4.1 QA/QC Plans for Generic SMPs

The QA/QC section of the Generic SMP describes an organization's QA/QC program with a focus on its policies, objective, organization, procedures, and system. The emphasis is on QA processes. If EPA's QA Program Plan guidance (e.g., U.S. EPA, 1980a, or U.S. EPA, 1985) is used, it should be referenced in the plan. If standard operating procedures (SOPs) are available that address sections or items in an appropriate manner, they may be referenced and appended. Plans must include the following items:

QA Policy--The organization should state its QA policy and describe in general terms its commitment to QA and its priority. The State should discuss the extent of its QA program (i.e., the activities covered).

Organization and Responsibilities--The description of the organization(s) with pesticide and ground water management responsibilities may be in the form of a table, chart, or narrative description. This section should list those individuals with QA responsibility and indicate to whom each reports. This section also discusses QA responsibilities and duties of QA personnel and management.

QA Management--The QA management section describes the processes involved and lines of communication used in managing the QA program from inception of a project to its completion. Flow charts may be used. Items addressed include formulation of project objectives, development of project designs and plans including translation of monitoring objectives into data quality indicators and criteria/objectives. This section also describes the development of QC activities to determine whether criteria are met, oversight activities assessing implementation of QC plans and procedures, and the assessment of the reports of data collection efforts. The section should also include those processes and procedures for preparing and approving plans and procedures; and procedures to review and assess performance, data, and information; for performing various audits; and for corrective action. The role of management, supervisory personnel, and QA personnel should be identified, and lines of communication, and decisionmaking should be indicated. Those making final decisions on quality should be identified. The function of audits and their frequency should be discussed.

Routine Data Quality Criteria/Objectives--Some agencies, programs, and laboratories have data quality acceptance criteria or policies in place which must be used when monitoring occurs. If so, States must describe these criteria including precision of estimates, acceptable precision and bias for analytical methods and measurements, resampling, confirmation, and acceptable error rates for computer entries. The information may be presented in tabular form.

Systems, Facilities, Equipment, and Services QA/QC--If not previously covered, States should describe the routine QA/QC processes and procedures for facilities, equipment, and services used in monitoring programs (including such items as automated data processing equipment, sampling, sample handling, analysis, and record archives). Standard Operating Procedures (SOPs) can be referenced and appended to save time. This section of the QA/QC report describes routine quality control procedures for data entry and processing.

5.4.2 Quality Assurance Project Plans for Pesticide SMPs

The QAPP for a Pesticide SMP should contain more detail than a Generic SMP QA/QC plan because it focuses on monitoring projects or programs for a specific chemical. EPA guidelines are available for the development of QAPPs, (e.g., U.S. EPA, 1980b); this or other EPA guidelines previously mentioned may be used). Whatever is used should be referenced. SOPs, publications, and manuals may be referenced and appended to the QAPPs to address specific items. If items were already covered in the Generic SMP States may then simply reference them. States should indicate that their contractors plan to follow FIFRA good laboratory practices.

Most previous EPA QA efforts focused on sampling and analysis of environmental media. Data may also be generated through the use of forms and questionnaires, such as those used in mapping and survey activities and well construction. States should describe the QC of these types of data gathering activities in appropriate sections in the QAPP. Descriptions typically include project description; sampling (questionnaire administration) procedures, sample (questionnaire) custody; internal QC checks; and data reduction, validation, and reporting. Because EPA has not developed formal QAPP guidance for these types of data gathering activities, States can discuss the QA/QC of such activities in a format that facilitates its review. Previously, QAPPs have been developed for mapping and statistics, including questionnaire administration, mapping activities, and data on pesticide usage for the National Survey of Pesticides in Drinking Water Wells. These documents are available from the National Technical Information Service.

The following items should be addressed in a QAPP for a Pesticide SMP, though not necessarily in this order. If an item is not relevant to the project under consideration, an explanation of why it is not must be included. If an item is covered elsewhere in the State Monitoring Plan, States should include a reference to the appropriate section.

1. ***Title Page***--The title page should include provisions for the signatures of approving personnel including the organization's project officer or director, the organization's responsible QA officer or manager (QAO or QAM), and, if applicable, the funding organization's project officer and QA official. Indicate data and the revision number on the title page. Inclusion of the date on subsequent pages of the document is recommended so that revisions to the QAPP can be tracked.

2. ***Table of Contents***--The table of contents should include an introduction, a serial listing of the quality assurance project plan components, and a listing of appendices required to augment the QAPP (i.e., SOPs). At the end of the table of contents, list all individuals receiving official copies of the QAPP and any subsequent revisions.

3. ***Project Description***--This section of the QAPP should include a general description of the project, including the experimental design. Where appropriate, include flow diagrams, tables, and charts; dates anticipated for start and completion; intended end use of acquired data; and statistical method or rationale for choosing sampling sites, frequency, and procedures. Reference other sections as appropriate.

4. ***Project Organization and Responsibility***--EPA is concerned that there will be a distinct separation of duties between those personnel involved with the conduct or direction of a study and those persons performing quality assurance on the same study (52 FR 48920). The project organization and line authority should be described. If good laboratory practices are followed, the project is required to have a single project director. This section should list the key individuals responsible for ensuring the collection of valid measurement data, the routine assessment of measurement systems for precision and accuracy, and the persons with supervisory oversight.

5. ***QC Objectives***--QC objectives, in terms of precision, accuracy, representativeness, comparability, and completeness, should be listed for each major parameter and for all pollutant measurement systems. Issues such as questionnaire administration and the overall design precision should be addressed as applicable. The QC objectives are actual numeric objectives when possible and should consider sources of error such as sampling and data entry, in addition to analytical error. Numeric objectives are usually best summarized in a tabular format -- if they are available. This section should also serve as the criteria for determining precision, accuracy, completeness, and representativeness of the data. The criteria for establishing the method detection limit should be presented. The effects of not meeting these objectives on decision making and litigious actions should be discussed.

6. ***Sampling Procedures***--For each major measurement parameter, including all pollutant measurement systems, describe the sampling procedure used (use a

reference if it is a standard procedure). This section of the QAPP should be consistent with the discussion in Section 5.5.4. Information about the sampling sites should be documented, including which sites, where they are, and how they were selected. This section should discuss the extent to which site selection affects the data validity. This section is very important because collection of representative data is critical to subsequent decision making and legal defensibility of the data. In addition, the following should be included as appropriate:

- Charts, tables, diagrams, and maps;
- Description of containers and reagents used;
- Procedures for sample preservation, transport, and storage;
- Techniques to avoid contamination of sampling equipment and containers;
- List of analytes and required sample volumes;
- Sample holding time;
- Time considerations for sample shipment; and
- Forms, notebooks, and procedures for recording sampling information.

7. ***Sample Custody***--When sample results are needed for legal purposes, it is important that chain-of-custody procedures be followed. The sample custody section of the QAPP should be consistent with section 5.5.4. Even if legal challenges are not anticipated, tracking of samples is a component of good laboratory and project management and should be addressed. If the State has SOPs for sample custody the SOPs may be referenced and attached. If not, the following procedures should be addressed in the QAPP.

For field sampling operations, the following should be included:

- Documentation of procedures for acquisition, storage, standardization, and handling of reagents and supplies;
- Procedures and forms for recording the time and location of sampling, as well as other relevant information associated with sample;
- Documentation of the specific sample preservation method and the integrity of the sample container;
- Description of the system for sample numbering and/or identification;

- Examples of pre-prepared sample labels containing all the information necessary for effective sample tracking (if computerized, describe the system to be used); and

- Standardized field tracking reporting forms to establish sample custody in the field prior to shipment.

For laboratory operations, the following should be described:

- Identification of the responsible party who acts as sample custodian at the laboratory facility and is authorized to sign for incoming field samples, obtain documents of shipment, and verify the data entered onto the sample custody record;

- Provision for a laboratory sample custody log consisting of serially numbered standard lab-tracking report sheets; and

- Specification of laboratory sample custody procedures for sample handling, storage, and dispersion for analysis.

8. Analytical Procedures--For each measurement parameter, include a reference to the applicable SOP or appropriate reference method, or a written description of the analytical procedure used. Officially approved EPA procedures should be used when available. When modifications of existing methods are used for analysis, the modification and validation of the method should be described in this section.

9. Calibration Procedures and Frequency--If the State has SOPs for these procedures, they may be referenced in this section. If not, the calibration procedures for both field and laboratory equipment should be noted in the QAPP. These procedures should include: a listing of the calibration standards; their sources(s), traceability, and purity; references of EPA or other methods and notation of any exceptions or variances used; a listing of accepted criteria for calibration measurement; and the schedule for recalibration of equipment.

10. Data Reduction, Validation, and Reporting--This section should briefly describe the following for each measurement parameter. For data reduction, the following topics should be addressed:

- Names of individuals responsible;

- Summary of data reduction procedures;

- Summary of statistical approach for reducing data;

- Examples of data sheets;

- Description of how blank and spike results will be treated in the calculations;

- Presentation of calculations and significant underlying assumptions;

- Computer system used for reduction; and

- Validation of software to be used.

For data validation, this section should include the following:

- Names of responsible individuals;

- Procedures for determining outliers and flagging data, and QC procedures for reviewing data;

- Identification of critical control points; and

- Amount of planned validation, e.g., 10 percent or 20 percent.

For data reporting, the text should include the names of responsible individuals, a flow chart of the data handling process, and identification of critical control points. In addition, the example format for the data report should be included.

11. Internal Quality Control Checks--This section should describe and/or reference all specific internal quality control methods to be followed. Guidance on internal QC is available in Taylor, 1987; Taylor 1985; and U.S. EPA, 1984. Examples of items States should consider include:

- Samples (split and collocated);
- Spikes and spike duplicates (field and laboratory);
- Replicates;
- Control chart procedures;
- Blanks (field and laboratory);
- Detection limit checks;
- Calibration checks, standards, and devices; and
- Reagent checks.

Internal QC checks may also be applied to nonanalytical activities such as questionnaire administration. These checks should include the use of consistent procedures, editing, resampling a subpopulation, and debriefing interviewers. A subsection on other activities can be added which addresses these aspects and which further emphasizes that QA/QC applies beyond just the analytical work.

12. Performance, Systems, and Data Audits--This section describes the periodic internal and external performance, systems, and data audits necessary to monitor the capability and performance of the total measurement system. This should include a schedule of all contractor audits, which should follow FIFRA good laboratory-practice regulations (as appropriate), and the personnel responsible for audits. If no audits are planned, provide a justification for this decision. The schedule for any interlaboratory performance evaluation studies should be given. Describe any data audits to ensure that raw data and reports are consistent.

13. Specific Routine Procedures Used To Assess Data Precision, Accuracy, and Completeness--This section describes routine procedures used to assess the precision, accuracy, and completeness of the measurement data. These procedures include the equations to calculate precision, accuracy, and completeness as well as methods used to gather data for calculations.

14. Corrective Action--This section discusses corrective action, and includes: trigger points; the prespecified conditions that will automatically require corrective action; personnel who initiate, approve, implement, evaluate, and report corrective action; and responses (what specific procedures will be used when corrective action is needed).

15. Quality Assurance Reporting Procedures--QAPPs address the need for periodic reporting to management on the performance of measurement systems and data quality. Requirements for reporting are specified for those projects conducted under FIFRA good laboratory practices. If FIFRA good laboratory practices are not being implemented, this section should include the name of the individual(s) preparing and receiving the reports; the type of report (i.e., written, oral, interim, final); the frequency of the reports; results of performances and data, and systems audits; significant QA problems and the recommended solutions; and limitations on the use of the measurement data.

5.5 Ground Water Sampling Procedures

Prior to collecting ground water samples, data quality objective (DQO) statements must be specified to ensure that adequate quality assurance is implemented and maintained throughout the data gathering process, and that the data generated are reliable and valid for the intended use. To ensure that the data are of adequate quality, DQOs for precision, accuracy, completeness, representativeness, and comparability must be established.

Precision is a measure of the repeatability and replicability of sample results, and helps define the level of effort in collecting field duplicate samples. Accuracy is a measure of how closely observed values conform to true values in order to evaluate the recovery of analyses such as spiked samples, matrix spikes, and matrix spike duplicates. Completeness is a measure of the amount of information that must be collected in the field to assure achievement of the objectives of sample collection. Representativeness and comparability are measures of how closely the measured results reflect the actual concentration or distribution for the chemical constituents in the sample and a measure of whether and to what degree a data set can be compared to other data sets.

Establishing DQOs at the beginning of a monitoring program will lead to a well developed ground water sampling effort. Prior to the collection of ground water samples, a comprehensive sampling protocol should be developed that addresses the DQOs. This protocol should address four major areas in implementing an effective sample collection program:

(1) Site selection (Section 5.5.1);

(2) Sample frequency schedule (Section 5.5.2);

(3) Field sampling and measurement procedures (Section 5.5.3); and

(4) Sample handling, custody, and transport (Section 5.5.4).

A copy of the protocol should be available to all individuals involved in ground water sampling. Problems or variances made in the field from the ordinal protocol should be carefully documented.[2]

5.5.1 Site Selection

The type of ground water source being sampled plays an important role in how the sampling protocol is developed and the sample collection procedures. Different sampling protocols must be used depending upon the ground water source being monitored. The type of ground water source will play a role in the type of sample collection equipment used and the procedures for purging the well (removing stagnant water) as well as filling sample bottles. The three main types of ground water sources are:

(1) water-supply and irrigation wells;
(2) monitoring wells; and
(3) seeps and springs.

Water supply and irrigation wells include wells that have been specifically constructed as a source of water for human or animal consumption and for irrigation purposes. These types of wells typically use mechanical pumps for obtaining water. These wells may pump at rates less than 1 gallon per minute or at rates greater than 1,000 gallons per minute. Others may only employ lowering a bucket down a well for water.

[2] Examples of ground water sampling protocols may be obtained from the California Department of Pesticide Regulation, Environmental Monitoring and Pest Management Branch, 1220 N Street, Sacramento, California 95814; and from the National Pesticide Survey, Office of Drinking Water (4601), U.S. Environmental Protection Agency, 401 M Street, S.W., Washington, D.C. 20406.

For the purpose of this document, monitoring wells are wells designed for the specific purpose of sampling ground water conditions. These wells might be built with a pump for easy sample collection or require bailing to obtain a sample.

For the purposes of this document, seeps are defined as areas where water oozes from the subsurface and springs are defined as areas where water flows from the subsurface onto the land surface without human assistance.

5.5.2 Sampling Frequency Schedule

The sample collection protocol should present a schedule for sampling at each sampling point. Determining the proper sampling frequency is critical to the success and cost-effectiveness of the sampling effort. Sampling too frequently can result in redundant information and unnecessary expense. Infrequent sampling can result in missing concentration trends, peak contaminant concentrations, and other temporal variabilities. In developing a sampling frequency schedule, States should consider the economic costs associated with the frequency in which well samples are taken.

This section provides information and guidance for determining sampling frequency schedules that are appropriate for SMP monitoring efforts. Temporal variations in ground water pesticide levels are discussed briefly, followed by guidance for selecting sampling frequencies for four different ground water monitoring approaches:

(1) Baseline monitoring;
(2) Problem identification monitoring;
(3) Response monitoring; and
(4) Evaluation monitoring.

Temporal Variations of Pesticides in Ground Water

Ground water chemistry is not static, especially in shallow aquifers. Noticeable changes in water chemistry occur in response to recharge cycles. Temporal variations in pesticide concentrations in ground water may be affected by a variety of factors, including:

- Timing, rates, and methods of pesticide application;
- Persistence or degradation of the pesticide in soil and ground water;
- Pesticide leaching rate;
- Variations in climate (e.g., precipitation, temperature);
- Hydrogeologic factors affecting aquifer recharge and ground water flow; and

- Anthropogenic factors affecting aquifer recharge and ground water flow (e.g., irrigation practices, well pumpage).

Recharge events (i.e., rainfall, snowmelt, and irrigation) following applications appear to be the events most responsible for transporting pesticide residues to ground water.

> EPA's Office of Research and Development (ORD) is currently sponsoring a three year temporal variability study of atrazine and nitrates in ground water. This Cooperative Agreement study between the State of Iowa and EPA uses a portion of Iowa's Statewide Rural Well-Water Survey (SWRL) network of wells. Contact: Matt Lorber, Exposure Assessment Group, Office of Health and Environmental Assessment, U.S. EPA Office of Research and Development; Telephone: (202) 260-8924.

Although there is substantial evidence that temporal variability (e.g., long-term and seasonal) of pesticide levels in ground water exists, this variability has not been characterized to the point that monitoring studies can be designed to accurately target points in time that sampled wells will be impacted. USGS and EPA are researching the optimum sampling frequencies as part of a study being carried out on the Delmarva peninsula.[3] The results are scheduled to be available in the Spring of 1994 and should prove useful for States in designing monitoring plans. However, almost all study designs will benefit from multiple sampling of wells in contrast to a single sample from a target population of wells. Wells may be sampled on a seasonal, monthly, or more frequent basis to identify temporal changes in pesticide concentrations. As information on seasonal variability is accrued from such efforts, the sampling schedules may be adjusted to better target temporal variations of interest.

The following describes considerations for scheduling sampling activities for each of the four common monitoring types described in Section 5.3.

1. Baseline Monitoring

Monitoring approaches to define baseline water quality conditions and trends typically involve large regions. For baseline monitoring random sampling can reduce effects of temporal variability of individual wells over a period of one or more years to ensure that well water samples are taken during all seasons and pesticide application cycles. Alternatively, a baseline survey may be stratified temporally on the basis of information on temporal variability obtained from other studies. This approach is

[3] The U.S. Geological Survey Circular 1080: Are Fertilizers and Pesticides in the Ground Water? A Case Study of the Delmarva Peninsula, Delaware, Maryland, and Virginia, U.S. Geological Survey, 1992, provides a non-technical description of the key findings of the NAWQA study. For more recent information on this study, contact the Ground Water Protection Section, Drinking Water/Ground Water Protection Branch, Water Management Division, U.S. EPA Region 3, 841 Chestnut Building, Philadelphia, PA 10107; Telephone: (215) 597-2786.

advantageous in that it minimizes the chances of temporal biases in the study results. If no significant temporal variability exists, either design (i.e., random or temporally stratified) will give equivalent results.

2. *Problem Identification Monitoring*

Problem identification monitoring is targeted to identify problems in areas where problems are most likely to occur. This type of monitoring focuses on site characteristics, practices, or events most likely to result in ground water contamination.

If little is known about the influence of temporal variability on the potential for pesticide contamination, a two-stage monitoring program may be established. In the first stage, problem identification monitoring is scheduled on a random basis. Targeted sampling is then conducted during the second stage to focus on particular time periods or further define any temporal variations detected in the first stage.

In some instances, previous data collected through baseline monitoring or prior knowledge of factors influencing temporal variability may be available. This information can be used to schedule sample collection during the time that pesticides are most likely to occur in ground water. In this manner, sampling efforts can be targeting temporally as well as spatially (location).

States can use mathematical models (simple or complex) to help predict the travel times and hence the lag between the recharge event and the potential arrival time of the pesticide at the monitoring point. However, model predictions always carry some degree of uncertainty; sampling events should be scheduled to bracket the most likely arrival time. Statistical methods can also be used to schedule sampling to maximize the probability of detecting contamination if it occurs. For example, this can be done simply by stratifying the sampling in time according to the most likely arrival time or somewhat likely arrival time.

3. *Response Monitoring*

The goal of response monitoring is to determine the nature, quantity, rate, and source of previously detected ground water contamination. Temporal variability must be considered when developing sampling protocols for this type of monitoring.

The sampling frequency and schedule for response or source monitoring should be sufficient to determine concentration trends and their temporal variability and, if necessary, to provide sufficient information for future predictions of contaminant migration from the source area. Cohen et al. (1986) suggest performing sampling at the start of the sampling program and continuing through several temporal cycles in order to identify temporal changes in ground water quality. Sanders et al. (1983) suggest a regular (e.g., monthly or weekly) sampling frequency to be adjusted as more information becomes available. Nacht (1983) presents an analytical method for determining sampling frequency based on the hazard rating of the contaminant.

4. *Evaluation Monitoring*

Evaluation monitoring is used to assess the effectiveness of an SMP or its components. Evaluation monitoring is mainly conducted when there are issues or concerns about the effectiveness of specific practices or about ground water quality.

To evaluate the effectiveness of a particular practice, sampling should be scheduled both before and after the implementation of the practice and should continue for as long as necessary to measure the full effects on ground water quality. Sampling should be scheduled to cover all temporal variables that could affect the impacts of a management measure on ground water quality (e.g., wet and dry weather, temperature extremes, crop rotations, irrigation events). Other considerations relevant to scheduling evaluation monitoring activities include:

- When using a paired well design, (sampling up and down gradient from an implementation site), a tolerance interval approach (e.g., Ward and Loftis 1986) may be used to detect sudden changes in ground water quality;

- A time trend approach (Spooner et al., 1986) may be useful in determining the time necessary for a BMP to be effective. Variations in land use, climate, and ground water hydrology are considered when interpreting results with respect to ground water quality/BMP relationships; and

- As part of an evaluation monitoring program, soil sampling can often provide valuable information on the migration rate and distribution of pesticides in the soil column. Cohen et al. (1986) provide guidelines on sampling frequency and methodology for soil sampling programs for investigating the mechanisms of pesticide migration to ground water.

5.5.3 Field Sampling and Measurement Procedures

Field sampling and measurement procedures include delineating, step-by-step, sampling procedures, and sample preservation and containerization requirements. States should consider the following five sampling and measurement procedures:

1. *Selection and Decontamination of Sampling Equipment*

Ground water sample collection procedures are based on the ground water source. Selection of the correct field equipment and requirements for well purging are based on the type of source sampled (i.e., water supply and irrigation well, monitoring weii, or seeps and springs).

Choose sample collection equipment (e.g., bailers) that does not alter the ground water sample through contact with sampler parts or through transfer and collection operations. Sampler parts made of fluoropolymers and stainless steel are preferred (U.S. EPA, 1986). In some cases, polypropylene materials may be preferable due to concerns over sorption of organic compounds to sampling equipment constructed of fluoropolymers. Because sample collection procedures may affect the analytical results, it is important that sampling equipment be compatible with the potential ground water constituents. This will enable consistency between collected samples and sampling events.

Ground water sampling equipment must be cleaned before use. The process used to decontaminate field equipment is generally the same as that used to clean labware. For organic constituents, sampling equipment should be washed with a nonphosphate detergent, rinsed with tap water then distilled water, and finally rinsed with a pesticide-grade solvent that will not interfere with the analytical method. Acetone can be used to aid in drying and to remove any organic residue that may have remained after washing. When decontaminating sampling equipment in the field, all rinsate solutions should be captured for disposal away from the wellhead in accordance with State or local regulations. Barcelona et al. (1985) suggest saving the distilled water rinsate for analysis to check cleaning efficiency. Solvent rinsate can also be saved for the same purpose.

Tubing used for water sample collection should be dedicated to an individual sampling location. Do not place decontaminated sampling equipment directly on the ground. It is best to store equipment in clean sealed containers after decontamination (e.g., plastic bags or coolers) for relocation to the well site. Handle clean equipment using rubber laboratory gloves.

Equipment blanks are used to determine if new or reused sample equipment has been properly decontaminated. They are prepared by passing high priority water through a decontaminated sample collection device and transferring this water to a sample container. Equipment blanks should be taken at the sampling site prior to sample collection. Field blanks are used to determine if contamination is introduced from sample collection activities. Field blanks are made by transporting high purity water to the field and using this water to prepare aliquots for each analytical parameter group under investigation. Field blanks collected using bailers should be decanted from the bailer into the sample container. If nondedicated pumps are used for sample collection, spectrographic-grade water should be pumped into a sample container to provide a field blank.

2. *Well Purging and Sample Collection*

Purging stagnant water in the well column is an important first step in well-water sampling. If the sampling pump and the purge pump are the same unit, standing water in the well should be removed or isolated. The purging method selected for monitoring wells ensure that stagnant water within the well casing is isolated or removed so that the sampling apparatus contacts or collects only fresh ground water representative of the aquifer. The chemical stability of purged water (pH, temperature, and conductance) should be considered when sampling fresh ground water and not stagnant water in the well casing or pump. Following well purging, sampling equipment should be flushed with at least 1 liter of representative well water prior to sample collection. The sample stream should not be allowed to cascade into the sample bottle. Ground water should be collected in the sample container by allowing the sample stream to gently flow along the sides of the collection container to avoid aeration of the sample. Volatile organic pesticide concentrations will be underestimated in aerated samples.

Ground water collected should not be composited into a large vessel for subsequent transfer into sample containers. If the sample collected from one well is split between multiple containers and if volatile organic compounds are not among the analytes, the sample containers should each be filled halfway using the first volumes withdrawn from the well. The remaining volume of each sample container should be filled adding half of each subsequent volume of ground water collected until the sample containers are full. Samples for volatile organics should be headspace-free. After collection of samples for the determination of nonvolatile organic compounds, the water level should be marked on the sample container with an indelible marker to monitor the sample for leakage.

At the time of collection the temperature of each ground water sample should be noted. To minimize the possibility of sample contamination, the measurement should not be made directly from the sample containers, but rather from an aliquot of the sampled water that can then be discarded. The following sections describe ground water sampling methods for a number of sampling points.

3. *Water-Supply and Irrigation Wells*

It is best to collect the discharge water as close to the well as possible. The pump should be allowed to purge the supply lines of stagnant water before the sample is collected. Monitoring pH and temperature during discharge is an effective indicator that fresh ground water is entering the supply system. Purging techniques utilized in EPA's National Pesticide Survey included drawing water from the wells until pH, temperature, and conductivity stabilized (U.S. EPA, 1990). The use of a flow cell will allow monitoring of pH and temperature during sample collection. It is important to clean the outlet of the valve in the distribution line from which the sample will be collected. Spray from the valve should be minimized while maintaining a gradual flow during sample collection. This allows a greater proportion of the water stream to be sampled and lessens additional aeration.

4. *Monitoring Wells*

It is most important, no matter what procedure is ultimately used for purging and sampling a particular well, that the same procedure be used consistently each time the well is sampled. For wells that monitor the phreatic surface of the aquifer, the pump intake should be near the phreatic (or "free water") surface and 5 to 10 casing volumes should be purged to remove all the stored water in the casing or screen. Once purging has been completed, the intake of the sampling apparatus should be situated below the level of the purging intake. Purge water should be discharged away from the well being sampled.

If a pump is used to collect ground water samples, the discharge should be constant so that pulsation of the discharge, which might aerate the sample, does not occur. The sample should be collected directly from the discharge. To avoid degassing the sample, discharge rates should not exceed 100 mL/min if volatile organics are to be analyzed. If bailers are used to collect the water samples, they should not be dropped or surged in the well. It is recommended that bailers used be equipped with a bottom valve that will facilitate control of the collection rate from the bailer.

5. *Seeps and Springs*

There are several methods that may be used to sample seeps and springs. The following methods were reported by Claussen (1982).

Seeps:

- Remove the soil zone to allow increased flow. This will usually result in samples that better represent the ground water; or
- Install a drive point (well point) into the soft earth associated with the seep. Use a suction pump or similar devices, if water does not flow from the well point, to sample the ground water.

Springs:

- Insert tubing into the fissure when the spring is located on a hillside, to allow nearly closed system sampling from the aquifer; or
- Use a suction pump or a miniature submersible pump, if the spring is located in a level area. Avoid sampling water that has been changed by surface or near surface contaminants.

5.5.4 Sample Handling, Custody, and Transport

Proper sample handling, custody and transport procedures are important to ensure the integrity of ground water samples. Protocols must be followed from the time a sample is collected until the time it is received and analyzed at the laboratory, and during any post-analysis storage. Protocols for sample handling, sample custody, and sample transported are described below:

1. *Sample Handling*

After collecting a ground water sample, preserve the sample in the field using the following sample analysis protocols (Section 5.6). Sample preservation that is appropriate to the analytes of interest should be undertaken to minimize biological and chemical degradation of each sample. This may include filtering and adding preservatives appropriate for the analytical method used. Place the sample directly into insulated boxes after collection. The main concerns in sample packing and shipping are to ensure protection against breakage and temperature fluctuations. The following sample handling procedures are recommended:

- Ship samples, if necessary, in insulated boxes or coolers.
- Wrap individual glass sample containers in plastic bubble wrap, placed in styrofoam holders, or otherwise package to prevent breakage during shipping.
- Place ice or Gel-Cold packs in each cooler. Gel-Cold packs should not be in direct contact with any of the glass sample containers or the samples may freeze. Ice should be sealed in plastic bags to prevent seepage during transport and to protect sample labels.
- Deliver samples to the laboratory within 24 hours after collecting and packing the sample.
- Ship all sample tracking paperwork with the shipment and ensure that chain-of-custody procedures are followed.

Coordination with the laboratory concerning frequency and number of samples is important to ensure that sample holding times are not exceeded. Notify the laboratory prior to sample collection to ensure expedited sample processing and analyzing.

2. *Sample Custody*

As each sample bottle is filled it should be labelled and assigned a sample tracking number. That number should be marked on the sample container, recorded on the chain-of-custody form, in a project notebook. Use a three-part label which includes numbered descriptive information to be placed on the sample container. The information placed on the sample container generally includes:

- Date and time of collection;
- Temperature of sample at collection;
- Well identification;
- Analytes; and
- Signature of sampler.

Place a security seal around the lid of each sample container. Security seals should also be placed around coolers or outer closures on other shipping containers. If samples are shipped to a laboratory, place a security seal around the lid of each sample container. It is sometimes necessary to place clear adhesive tape over the seal to protect it from excess moisture. Sample custody begins, in all cases, at the time of sample collection by placing the sample with ice in an ice chest, or other appropriate container(s), in the presence of the field custodian. At this time the field custodian, often the sampler, will complete a line item on the field chain-of-custody form. This chain-of-custody form is completed by all individuals who assume responsibility for the sample(s). Sample custody protocols are discussed further in Section 5.4

3. *Sample Transport*

Samples sent by overnight carrier to the laboratory must be packaged and shipped in compliance with current U.S. Department of Transportation and International Air Transport Association dangerous goods regulations. Enclose sample chain-of-custody records and any other shipping documentation in a waterproof plastic bag and tape it to the underside of the shipment container. The container should be taped securely shut and a security seal placed around the container.

5.6 Ground Water Sample Analysis

Monitoring plans should include protocols for sample analysis. These protocols include the compounds to be measured, the analytical methods used to measure each compound, and laboratory performance criteria (e.g., detection limit, quantitation limit, and precision requirements). The performance criteria should be consistent with criteria in the quality assurance/quality control (QA/QC) plan for the monitoring effort (see Section 5.4). In addition, the QA/QC plan should include QC practices specified in each method used.

5.6.1 Analytic Methods

The method(s) used for sample analysis may differ between Generic SMPs and Pesticide SMPs. Monitoring for several pesticides can sometimes be done efficiently with multi-residue methods, allowing simultaneous measurement of a number of pesticide compounds. Multi-residue methods are cost-effective in that they enable the analyst to screen for a variety of pesticides with a single scan. Such multi-residue methods, however, tend to be less precise for individual analytes and therefore tend to have higher detection limits than methods concentrating on a single analyte.[4]

For individual pesticides, EPA requires pesticide registrants to provide EPA with data on the performance of those soil and water chemistry methods used to develop laboratory and/or field residue data (exposure, environmental fate, and ecological effects studies) to support registration or reregistration. EPA will accept methods, both single and multi-analyte, that meet acceptable performance criteria.

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[4] Recent research suggests that the frequency of herbicide detection is affected by reporting limits. An ongoing study by the U.S.G.S. on the occurrence and distribution of selected herbicides, atrazine metabolites, and nitrate in aquifers within 50 feet of the land surface in the Mid-Continental United States has found a non-linear increase in atrazine detection frequency with decreases in reporting limit. D.W. Kolfin and M.R. Burkart, "Herbicides and Nitrate in Near-Surface Aquifers in the Mid-Continental United States, 1991" EOS, Transactions American Geophysical Union, Vol. 73, No. 43, October 27, 1992/Supplement 1992 Fall meeting, p. 229.

When selecting an analytical method for a specific pesticide, several factors should be considered. The method detection level (MDL) and practical quantitation limit (PQL) should be appropriate for the objectives of the analysis. For example, the PQL should be at or below the concentration of interest (e.g., the level at which specific actions will be taken). A discussion of reporting limits for detections of pesticides in ground water is provided in Chapter 7. The method also should be selective for the analyte of interest and free of any interference problems from other substances likely to be present in the sample. If the more nonselective methods are used (e.g., gas chromatography [GC] with electron capture detection or nitrogen/phosphorous detection for sample screening), any detections should be confirmed using a different method (e.g., a second GC column with a different polarity).

5.6.2 EPA Methods

Because of the chemical variety of pesticides and the differing needs of its regulatory programs, the EPA has developed a variety of analytical methods for the detection and measurement of pesticides in water samples. These methods include data on method performance and method-specific QC practices. Analytical methods for pesticides have been developed for the Safe Drinking Water Act (SDWA) regulations (500-series methods), the National Pesticide Survey (Methods 1 - 7), the Clean Water Act wastewater regulations (600-series methods), the Resource Conservation and Recovery Act hazardous waste regulations (8000-series methods), and the National Sewage Sludge Survey (Method 1618).

The 500-series drinking water methods and the National Pesticide Survey methods are available for the analysis of pesticides in ground water and other potential drinking water sources. The 500-series methods are the same as National Pesticide Survey Methods 1, 2, 3, 5, and 7. These methods employ chromatographic techniques (gas chromatography or high-pressure liquid chromatography) coupled with sample preparation and cleanup methods and specific detectors appropriate for the analytes of interest. Basic information about these methods is presented in Table 5-6. Most are multiresidue methods, and therefore are not sensitive at low levels. The 600-series and 8000-series methods are very similar to the 500-series methods and have been evaluated for certain pesticides not included in the analyte lists for the former methods. Table 5-7 lists available EPA analytical methods for a number of pesticides.

When selecting analytic methods for baseline monitoring, consideration should be given to reporting all concentration data, without reporting limits. The National Pesticide Survey Phase II Report recommends that if statistical analysis of data is anticipated, "in addition to reporting data that have satisfied both qualitative confirmation and quantitative measurement (equivalent to data exceeding specified minimum reporting levels), a second tier of data should be reported that have been qualitatively confirmed but that have not been qualitatively measured at the specified levels of precision." (U.S. EPA 1992) By reporting such results, along with sufficient information to allow users to judge their reliability, statistical analyses that involve only the identity of the analyte are enhanced.

Table 5-6. SDWA and National Pesticide Survey Analytical Methods for Pesticides in Ground Water

Method Number	Title	Comments
504 NPS Method 7	1,2-Dibromoethane (EDB) and 1,2-Dibromo-3-Chlorpropane (DBCP) in Water by Microextraction and Gas Chromatography	EDB and DBCP. Microextraction with hexane (35 mL sample/2 mL hexane) Capillary column, electron capture detector. Confirm with dissimilar column.
505	Analysis of Organohalide Pesticides and Commercial Polychlorinated Biphenyl Products in Water by Microextraction and Gas Chromatography	18 pesticides. Microextraction with hexane (35 mL sample/2 mL hexane) Capillary column, electron capture detector. Confirm with alternative column or GC/MS.
507 NPS Method 1	Determination of Nitrogen- and Phosphorous-Containing Pesticides in Water by Gas Chromatography with an Electron Capture Detector	39 pesticides. Liquid/liquid extraction with methylene chloride. Capillary column. Confirm with alternate column.
508 NPS Method 2	Determination of Chlorinated Pesticides in Water by Gas Chromatography with an Electron Capture Detector	25 pesticides. Liquid/liquid extraction with methylene chloride. Capillary column. Confirm with alternate column.
515.1 NPS Method 3	Determination of Chlorinated Acids in Water by Gas Chromatography with an Electron Capture Detector	13 pesticides. Hydrolysis with sodium hydroxide, methylene chloride wash, liquid/liquid extraction with ethyl ether, derivatize to esters with diazomethane. Optional Florisil cleanup. Capillary column, confirm with alternate column.
525	Determination of Pesticides in Ground water by High Performance Liquid Chromatography with an Ultraviolet Detector	16+ pesticides. LSE cartridge extraction with methylene chloride elution. Applicable to large number of analytes; can be used for new analytes after obtaining sufficient precision and accuracy data.
NPS Method 4	Determination of Organic Compounds in Drinking Water by Liquid-Solid Extraction and Capillary Column Gas Chromatography/Mass Spectrometry	16 pesticides. Liquid/liquid extraction with methylene chloride. Primary and confirmational HPLC columns.
531.1 NPS Method 5	Measurement of N-Methylcarbamoxyloximes and N-Methyl Carbamates in Water by Direct Aqueous Injection HPLC with Post-Column Derivatization	10 pesticides. Uses gradient elution chromatography with sodium hydroxide hydrolysis after elution. Primary and confirmational high performance liquid chromatography (HPLC) columns.
NPS Method 6	Determination of Ethylene Thiourea (ETU) in Ground Water by Gas Chromatography with a Nitrogen-Phosphorous Detector	1 pesticide. Liquid chromatography cleanup. Capillary column. Confirm with alternate column.

References: U.S. EPA (1988), Munch et al. (1990).

Table 5-7: Analytical Methods for Selected Pesticides

Pesticide	EPA Method	Pesticide	EPA Method
Acefluorfen	515.1	Demeton	622,8141
Ametryn	507,619	Diallate	1618
Aldrin	505,508,525,608,8081	Diazinon(a)	507,622,8141
Aninocarb	632	Dicamba	515.1,615,8151
Atraton	507	3,5-Dichlorobenzoic acid	515.1
Atrazine	507	Dichlofenthion	1618
Atrazine deethylated	Method 4	Dichlorprop	515.1,615,8151
Barban	Method 4	Dichlorvos	507,622,8141
Baygon	531.1	Diclone	1618
Bentazon	515.1	Dieldrin	505,508,525,608,8081
Bromacil	507	Dimethoate	8141
Butachlor	507,525	Dinoseb	515.1,615,8151
Butylate	507	Dioxathion	1618
Captan	1618	Diphenaniid	507
Captofol	1618	Diquat	549
Carbaryl	531.1	Disulfoton	507,622,8141
Carbofenothion	1618	Disulfoton sulfone	507
Carbofuran phenol	Method 4	Disulfoton sulfoxide	507
Carboxin	507	Diuron	632,Method 4
Chloramben	515.1	Endosulfan 1	508,608,8081
Chlorfevinphos	1618	Endosulfan 11	508,608,8081
Chlorneb	508	Endosulfan sulfate	508,608,8081
Chlorobenzilate(a)	508,1618	Endothall	548
Chlorothalonil	508,Method 4	Endrin aldehyde	508,608,8081
Chlorpropham	507,632,	Endrin ketone	1618,8081
Chlorpyrifos	622,8141	EPN	622,8141
Coumaphos	622,8141	EPTC	507
Crotoxyphos	1618	Ethion	1618
Cyanazine	Method 4	Ethoprop	507,622,8141
Cycloate	507	Ethyl azinphos	1618
2,4-DB	515.1,615,8151	Ethyl parathion	8141
D-2(ethylhexyladipate)	506,525	Etridiazole	508
D-2(ethylhexylphthalcites)	506,525	Famphur	8141
Dalapon	515.1	Fenamiphos	507
DCPA	508	Fenaniphos sulfone	Method 4
DCPA acid metabolites	515.1	Fenaniphos sulfoxide	Method 4
4,4'-DDD	508,608,8081	Fenarimol	507
4,4'-DDE	508,608,8081	Fensulfothion	622,8141
4,4'-DDT	508,608,8081	Fenthion	622,8141

Table 5-7: Analytical Methods for Selected Pesticides (continued)

Pesticide	EPA Method	Pesticide	EPA Method
Fluometuron	632,Method 4	Norflurazon	507
Fluridone	507	Oxamyl (vydate)	531.1
Glyphosate	547	PCNB	1618
HCH-alpha (alpha-BHC)	508,608,8081	Pebulate	507
HCH-beta (beta-BHC)	508,608,8081	cis-Permethrin	508
HCH-delta(a) (delta-BHC)	508,608,8081	trans-Permethrin	508
Hexazinone	507,633	Phorate	8141
Hexachlorobenzene	505,508,525	Phosmet	1618
Hexachlorocyclopentadiene	505,525	Picloram	515.1
3-Hydroxycarbofuran	531.1	Prometon	507,619
5-Hydroxy Dicamba	515.1	Prometryn	507,619
Isodrin	1618,8081	Pronamide(a)	507
3-Ketocarbofuran phenol	Method 4	Propachlor	508,525
Leptophos	1618,8081	Propanil	Method 4
Linuron	632,Method 4	Propazine	507,619
Malathion	8141	Propham	632,Method 4
MCPP	615,8151	Propoxur	531,632
MCPA	615,8151	Ronnel	622,8141
Merphos	507,622,8141	Simazine	505,507,525,619,Method 1
Methiocarb	531.1,632	Simeuyn	507
Methyl azinphos	622,8141	Stirofos	507
Methyl chlorpyrifos	622,8141	Sulfotepp	1618,8141
Methyl parathion	622,8141	Sulprofos (Bolstar)	622,8141
Methyl paraoxon	507	Swep	Method 4
Methomyl	531.1,531,632	2,3,7,8-TCDD (Dioxin)	513
Metolachlor	507,525	2,4,5-T	515.1,615
Metribuzin DA	Method 4	Tebuthiuron	507
Mevinphos	507,622,8141	Terbacil	507
Mexacarbate	632	Terbufos(a)	507,622,8141
MGK 264	507	Tebuthiuron	Method 4,8151
Mirex	1618,8081	Terbuthylazine	619
Mohnate	507	Terbutryn	507,619
Monuron	632	Tetrachlorvinphos	8141
Naled	622,8141	Tokuthian (Prothiofos)	8141
Napropaniide	507	Triademefon	507
Neburon	Method 4	Trichloronate	622,8141
Nitrofen	1618	Tricyclazole	507
4-Nitrophenol	515.1	Trifluralin	508,1618
cis-Nonachlor	505	Vemolate	507
trans-Nonachlor	505,525		

Another consideration when monitoring ground water for specific pesticides is the possible presence of degradates of the compounds of interest. Pesticides can degrade to compounds that may be as toxic or more toxic than the parent compounds. Detection of these metabolites or degradation products in ground water is evidence that the parent compounds are leaching into the environment. If possible, analytical methods should be selected to detect degradates as well as the parent compounds. Examples of pesticide degradates include aldicarb sulfone and aldicarb sulfoxide (from aldicarb), and disulfoton sulfone and disulfoton sulfoxide (from disulfoton), and ethylene thiourea (ETU). If possible, a mass balance should be performed using information on detected parent compounds and degradates to substantiate analytical results.

5.6.3 Immunoassay Methods

Immunoassay techniques have recently been developed for some of the triazine pesticides (e.g., atrazine). The USGS used these methods extensively in their Midwest Water-Quality Initiative surveys (Brown et al., 1990). Immunoassay techniques represent immunochemical technology transferred from clinical chemistry to the analysis of environmental samples. Each is based on a highly specific antigen-antibody reaction. These techniques have a high sample capacity and throughput. They are especially useful for screening samples in the field. They are sensitive, selective, precise, rapid, cost-effective, and potentially applicable to a wide range of contaminants. A 1989 demonstration of an immunoassay technique for pentachlorophenol in water showed that the method requires about 30 minutes to perform, has a detection limit of about 2 ppb, a linear dynamic range from 2 to 40 ppb, and can be used with a standard portable spectrophotometer for standard curve generation and quantitation. The method was comparable to GC/MS in precision and accuracy (Koglin and Poziomek, 1990). Immunoassay techniques for a variety of chemicals, including pesticides, are currently under development and evaluation at the Agency and elsewhere. The detection limit for screening triazines using a colorimetric spectrophotometer ranges from 0.1 to 0.2 ppm. The cost for screening triazines using colorimetric techniques is one-fourth to one fifth of the cost of a GS analysis. Thurman et al. (1990) describe a successful laboratory application of immunoassay techniques for triazine herbicide residues.

Standard QA/QC requirements (e.g., recovery, spikes, blanks) are required for immunoassay analyses. Positive immunoassay results should be confirmed with traditional analytical methods (e.g., GC, HPLC, and GC/MS) in order to clearly identify and quantitate the analytes of interest. Confirmations should include pesticide residues at or above the limit of quantitation, using traditional analytical methods. Confirmation is necessary to reduce the impact of false positives. EPA recommends that a systematic number of negative immunoassay water samples also be reanalyzed with traditional analytical methods to rule out the possibility of false negatives. Samples identified for reanalysis should be randomly selected using standard statistical selection techniques.

A caution on the use of immunoassay techniques: Although they are simple in operation, expertise is required in interpreting results, especially those involving colorimetric determinations in the field. Field analysts should be familiar with the methods prior to conducting analyses, and results should be calibrated with respect to colorimetric judgements.

5.6.4 Methods for Reducing Monitoring Costs

States can develop a cost-effective ground water monitoring program while fulfilling the data quality objectives of the sampling effort. Developing a ground water monitoring program requires a detailed description of the procedures for selecting sampling locations and the step-by-step standard operating procedures for collecting and analyzing samples. Four keys areas should be considered in determining sampling locations and developing sampling and analysis procedures.

(1) Sampling existing wells;

(2) Selecting well sampling locations that are representative of the aquifer rather than specific local land features;

(3) Collecting split samples; and

(4) Selecting a broad spectrum analytical technique.

Selecting existing wells (i.e., domestic, municipal, irrigation, and industrial supply wells) can reduce sampling costs by avoiding expenses associated with drilling a new well. In addition, careful consideration should be given to selecting wells located in areas that are representative of the aquifer rather than site-specific land features. Selecting wells based on geologic and aquifer characteristics reduces the number of wells that have to be installed and monitored compared to wells that may only characterize local land features (e.g., pesticide loading/unloading areas).

> The U.S. EPA Office of Research and Development (ORD) in a cooperative research agreement with the University of Iowa is conducting a study, "Temporal Variability of Atrazine Contamination of Private Rural Well Water Supplies," that provides cost-effective management techniques for conducting a water quality monitoring program. The techniques considered by this study include making owners responsible for taking samples and using immunoassay techniques to screen for contamination. By implementing these cost cutting techniques, samples collected from the same well over a period of time can be used to adequately characterize the extent and degree of human risk exposure. For more information, contact Matt Lorber, U.S. EPA Office of Research and Development, (202) 260-8924.

Collecting split samples can also reduce monitoring costs. Split samples, which are allocated by dividing a field sample into two separate bottles can permit independent analysis (e.g., confirmation of detection) of the sample at a latter date without incurring additional field sampling costs. Finally, selecting an approved EPA multi-residue method can reduce analytical preparation and extraction costs compared to a pesticide-specific analytical procedure.

5.7 References

Aller, L., T.W. Bennett, G. Hackett, R.J. Petty, J.H. Lehr, H. Sedoris, D.M. Nielsen, and J.E. Denne. 1990. Handbook of Suggested Practices for the Design and Installation of Ground Water Monitoring Wells. National Water Well Association, Dublin, OH. NTIS PB90-159807. 398 pp.

Barcelona, M.J. 1985. Illinois State Water Survey. Champaign, IL. SWS Contract Report 374. NTIS PB86-137304. 93 pp.

Brown, D.E., M.T. Meyer, M.L. Pomes, E.M. Thurman, and D.A. Goolsby. 1990. "Temporal variations of trizone and chloroacetanilide herbicide concentrations in selected streams in the Midwestern United States, April-August 1990." Abstract submitted for publication in EOS and for presentation at the American Geophysical Union Fall Meeting, San Francisco, CA.

Canter, L.W., R.C. Knox, and D.M. Fairchild. 1987. Ground Water Quality Protection. Chelsea, Michigan: Lewis Publishers, Inc.

Clark, T.P., and Trippler. 1977. "Design and Operation of an Ambient Ground Water Quality Monitoring Program for Minnesota." NWWA Symposium, National Water Well Association. Worthington, OH.

Claussen, H.C. 1982. Guidelines and Techniques for Obtaining Water Samples that Accurately Represent the Water Quality of an Aquifer. U.S. Geological Survey, Water Resources Division.

Cochran, W.G. 1967. Sampling Techniques. Second Edition. New York, NY: John Wiley and Sons, Inc.

Cohen, S.Z., S.M. Creeger, R.F. Carsel, and C.G. Enfield. 1984. In: Treatment and Disposal of Pesticide Wastes. Editors: R.F. Krueder, and J.N. Seiber. American Chemical Society. Washington, D.C. ACS Symposium Series No. 259:297-325.

Cohen, S.Z., C. Eiden, and M.N. Lorber. 1986. "Monitoring Ground Water for Pesticides." In: Evaluation of Pesticides in Ground Water. Editors: Garner, W.Y., R.C. Honeycutt, and H.N. Nigg. American Chemical Society. pp. 170-196.

Ehteshami, M., R.C. Peralta, H. Eisele, H. Deer, and T. Tindall. 1991. "Assessing Pesticide Contamination to Ground Water: A Rapid Approach." *Ground Water*. 29:862-868.

Gilbert, R.O. 1987. Statistical Methods for Environmental Pollution Monitoring. N.Y.: Van Nostrand Reinhold. 320 pp.

Goolsby, D.A., E.M. Thurman, M.L. Clark, M.L. Pomes. 1990. "Immunassays for Trace Chemicals Analysis." In: Monitoring Toxic Chemicals in Humans, Food, and the Environment. Editors: Vanderlaan, M., L.H. Stanker, B.E. Watkins, and D.W. Roberts. American Chemical Society. ACS Symposium Series No. 450. 13 pp.

Hallberg, G.R., R.D. Libra, and B.E. Hoyer. 1985. "Nonpoint Source Contamination of Ground Water in Karst Carbonate Aquifers in Iowa." In: Perspectives on Nonpoint Source Pollution. U.S. Environmental Protection Agency. EPA 440/5-85-001. pp. 109-114.

Hines, J.W., W. Haugan, D. DeLuca. 1990. Minnesota Department of Agriculture Water Quality Monitoring: Biennial Report. Minnesota Department of Agriculture. 30 pp.

Kearl, P.M., N.E. Korte, and T.A. Cronk. 1991. "Suggested Modifications to Ground Water Sampling Procedures Based on Observations from the Colloidal Borescope." *Environ. Sci. Techol.*, 1991:25. 3 pp.

Klaseus, T.G., G. Buzicky, and E. Schneider. 1988. Pesticides and Groundwater: Surveys of Selected Minnesota Wells. Minnesota Department of Health and Minnesota Department of Agriculture. 95 pp.

Klaseus, T.G., and J. Hines. 1988. Pesticides and Groundwater: A Survey of Selected Private Wells in Minnesota. Minnesota Department of Health. 76 pp.

Lemasters, G. and D.J. Doyle. 1989. Grade A Dairy Farm Well Quality Survey. Madison, WI: Wisconsin Department of Agriculture, Trade and Consumer Protection and Wisconsin Agricultural Statistics Service.

Nacht, S.J. 1983. "Monitoring Sampling Protocol Considerations." *Groundwater Monitoring Review.*

Nielson, D.M. and A.I. Johnson. 1990. Ground Water and Vadose Zone Monitoring. ASTM, Philadelphia, PA. 313 pp.

Parker, L.V., A.D. Hewitt, and T.F. Jenkins. 1990. "Influence of Casing Materials on Trace-Level Chemicals in Well Water." *Ground Water Monitoring Review* 10(2):146-155.

Pomes, M.L. and E.M. Thurman. 1990. "Comparison of microtitre place immunoassay (ELISA) and GC/MS for herbicides in stormflow samples." Abstract submitted for publication in EOS and presented at the San Francisco American Geophysical Union 1990 Fall Meeting.

Quinlan, J.F. and R.O. Ewers. 1986. "Reliable Monitoring in Karst Terrains: It can be done, but not by an EPA-approved method." *Groundwater Monitoring Review.* National Water Well Association. pp. 4-6.

Quinlan, J.F. 1989. Ground Water Monitoring in Karst Terrains: Recommended Protocols and Implicit Assumptions. EPA Inter-Agency Unpublished Document. 79 pp.

Quinlan, J.F. and R.O. Ewers. 1985. "Ground Water Flow in Limestone Terrains: Strategy Rationale and Procedure for Reliable, Efficient Monitoring of Ground Water Quality in Karst Areas. Proceedings of Fifth National Symposium and Exposition on Aquifer Restoration, Columbus, OH. pp. 197-234.

Rhode Island Department of Environmental Management. 1990. Ground Water Section. Rhode Island Private Well Survey Final Report.

Rogers, C. April, 1991. Personal Communication. Texas Water Commission.

Sanders, T.G., R.C. Ward, J. C. Loftis, T.D. Steele, D.D. Adrian, and V. Yevjevich. 1983. Design of Networks for Monitoring Water Quality. Littleton, CO: Water Resources Publications.

Schaeffer, R.L., W. Mendenhall, and L. Ott. 1979. Elementary Survey Sampling. Second edition. North Scituate, MA: Duxbury Press.

Spooner, J.C., C.A. Jamieson, R.P. Mass, S.A. Dressing, M.D. Smolen, and F.J. Humenik. 1986. Rural Clean Water Program Status Report on the CM&E Projects 1985 - Supplement Report: Analysis Methods. Biological and Agricultural Engineering Department, N.C. State University, Raleigh.

Taylor, John K. 1987. Quality Assurance of Chemical Measurements. Chelsea, MI. Lewis Publishers, Inc.

Taylor, John K. 1985. Principles of Quality Assurance of Chemical Measurements. U.S. Department of Commerce, National Bureau of Standards. NTIS PB 85-177947.

Thornhill, J.T. 1989. Accuracy of Depth to Water Measurements. U.S. EPA. Robert S. Kerr Environmental Research Laboratory, Ada, OK. EPA 540/4-89/002.

Thurman et al. 1990. "Enzyme-Linked Immunosorbent Assay Compared with Gas Chromatography/Mass Spectrometry for the Determination of Triazine Herbicides in Water." *Analytical Chemistry*. 62(18):2043-2048.

Thurman, E.M., D.A. Goolsby, M.T. Meyer, and D.W. Kolpin. 1991. Herbicides in Surface Waters of the Midwestern United States: The Effect of Spring Flush. U.S. Geological Survey, Kansas. 3 pp.

U.S. EPA. 1991. Ground Water Handbook (revised), Volume II: Methodology. U.S. EPA-ORD. Cincinnati, OH. EPA 625/6-90/016b.

U.S. EPA. 1991. Handbook of Suggested Practices for the Design and Installation of Ground Water Monitoring Wells. U.S. EPA-ORD. Cincinnati, OH. EPA 600/4-8a/034.

U.S. EPA. 1990. National Survey of Pesticides in Drinking Water Wells - Phase I Report. EPA 570/19-90-015. NTIS PB91-125765.

U.S. EPA. 1987. Ground Water Handbook. U.S. EPA-ORD. Cincinnati, OH. EPA 625/6-87/016.

U.S. EPA, Office of Waste Programs Enforcement, Office of Solid Waste and Emergency Response. 1986. RCRA Ground Water Monitoring Technical Enforcement Guidance Document. OSWER-99501.1. 317 pp.

U.S. EPA. 1986. RCRA Ground Water Monitoring: Technical Enforcement Guidance Document.

U.S. EPA, Office of Research and Development, Quality Assurance Management Staff. 1985. Guidelines and Specifications for Preparing Quality Assurance Program Plans for National Program Offices, ORD Headquarters, and ORD Laboratories.

U.S. EPA. 1985. Practical Guide for Ground Water Sampling. U.S. EPA-ORD. Cincinnati, OH. EPA 600/2-85/104.

U.S. EPA, Office of Research and Development, Quality Assurance Management Staff. 1984. "Chapter 5: Calculation of Precision, Bias, and Method Detection Limit for Chemical and Physical Measurements."

U.S. EPA. 1981. Manual of Ground Water Sampling Procedures. EPA 600/2-81/160. National Water Well Association (NWWA), Dublin, OH or National Technical Information Service (NTIS), Springfield, VA.

U.S. EPA, Office of Research and Development, Quality Assurance Management Staff. 1980a. Guidelines and Specifications for Preparing Quality Assurance Program Plans. QAMS-004/80.

U.S. EPA, Office of Research and Development, Quality Assurance Management Staff. 1980b. Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans. QAMS-005/80.

U.S. EPA. 1992. National Pesticide Survey Quality Assurance Plans:

Battelle - Columbus. February. Quality Assurance Project Plan for the National Pesticide Survey of Drinking Water Wells: Analytical Method 6 -- Ethylene thiourea. EPA 810/B-92/012.

Clean Harbors Incorporated. February. Quality Assurance Project Plan for the National Pesticide Survey of Drinking Water Wells: Analytical Method 2 -- Chlorinated Pesticides. EPA 810/B-92/003.

Environmental Chemistry Laboratory of the Office of Pesticide Programs. February. Quality Assurance Project Plan for the National Pesticide Survey of Drinking Water Wells: Analytical Method 1. EPA 810/B-92/010.

Environmental Chemistry Section of the Office of Pesticide Programs. February. Quality Assurance Project Plan for the National Pesticide Survey of Drinking Water Wells: Analytical Method 3. EPA 810/B-92/011.

ES&E. February. Quality Assurance Project Plan for the National Pesticide Survey of Drinking Water Wells: Analytical Method 5 -- Methyl carbamates. EPA 810/B-92/005.

ES&E. February. Quality Assurance Project Plan for the National Pesticide Survey of Drinking Water Wells: Analytical Method 7 -- Fumigants. EPA 810/B-92/007.

ETU, Environmental Chemistry Section of the Office of Pesticide Programs. February. Quality Assurance Project Plan for the National Pesticide Survey of Drinking Water Wells: Analytical Method 6. EPA 810/B-92/006.

ICF Incorporated. February. Quality Assurance Project Plan for the National Pesticide Survey of Drinking Water Wells: Hydrogeologic Characterization and Second-Stage Stratification Activities. EPA 810/B-92/013.

ICF Incorporated. February. Quality Assurance Project Plan for the National Pesticide Survey of Drinking Water Wells: Well Sampling, Data Collection, and Processing. EPA 810/B-92/014.

ICF Incorporated and Westat Incorporated. February. Quality Assurance Project Plan for the National Pesticide Survey of Drinking Water Wells: Survey Statistics, Data Collection and Processing. EPA 810/B-92/015.

Montgomery Laboratories. February. Quality Assurance Project Plan for the National Pesticide Survey of Drinking Water Wells: Analytical Method 1 -- Phosphorus Pesticides and Analytical Method 3 - Chlorinated Acid Herbicides. EPA 810/B-92/002.

Montgomery Laboratories. February. Quality Assurance Project Plan for the National Pesticide Survey of Drinking Water Wells: Analytical Method 9 -- Nitrate and Nitrite. EPA 810/B-92/008.

Quality Assurance Program Plan for the National Pesticide Survey of Drinking Water Wells. February. EPA 810/B-92/001.

Radian Corporation. February. Quality Assurance Project Plan for the National Pesticide Survey of Drinking Water Wells: Analytical Method 4 -- Carbamates. EPA 810/B-92/004.

Technical Support Division, Office of Drinking Water and Risk Reduction Engineering Lab, Office of Research and Development. February. Quality Assurance Project Plan for the National Pesticide Survey of Drinking Water Wells: Referee Analyses for Method 2 -- Organochlorine Pesticides, Method 4 -- Carbamates, Method 5 -- Methylcarbamates, Method 7 -- Fumigants, and Method 9 -- Nitrate/Nitrite. EPA 810/B-92/009.

Ward, R.C. and J. C. Loftis. 1986. "Establishing Statistical Design Criteria for Water Quality Monitoring Systems: Review and Synthesis." *Water Resources Bulletin* 22(5):759-767.

Wisconsin Department of Agriculture, Trade, and Consumer Protection and Wisconsin Agricultural Statistics Service. 1989. Wisconsin Grade A Dairy Farm Well Water Quality Survey. 36 pp.

Chapter 6

Response Plan

EPA's priorities for responding to ground water contamination by pesticides are to limit the risks of adverse effects to human health first and then to restore currently used and reasonably expected drinking water supplies and ground water closely hydrologically connected to surface waters, whenever such restorations are practicable and attainable. In making remedial decisions, a realistic approach to restoration should be taken based on actual and reasonably expected uses of the resource as well as social and economic values. This chapter provides a framework for addressing the SMP component involving response to the detection of pesticides in ground water. Many different responses to subsurface contamination are possible. The appropriate response for a given incident of contamination is usually a function of the level and source of contamination, a State's ground water protection philosophy, and the use and value of the ground water that has been contaminated. Based on a determination of the cause of contamination and the risks associated with the contamination, technical and management information may be combined to determine how to prevent future occurrences of a similar nature.

The Guidance for Pesticides and Ground Water State Management Plans provides that both a Generic and Pesticide State Management Plan should:

- Describe the actions the State will take if a pesticide has exceeded or is expected to exceed reference points in ground water. When a pesticide level in ground water approaches, reaches, or exceeds an MCL or other reference point as a result of normal agricultural use, an aggressive stance should be taken, including the possibility of prohibiting further use of the pesticide in the affected areas. Detections below reference points should also trigger actions to prevent contamination with the potential to pose risks to human health and the environment (See Component 7.) The State's response section of its SMP may overlap with its prevention section. However, it must at a minimum pick up where the prevention section left off.

- Describe the steps that will be taken, and who will be responsible for: (1) identifying, if possible, the source of contamination, (2) ascertaining whether contamination resulted from normal use in accordance with label directions and other requirements, or from misuse or accident, and (3) determining whether the detection was found in a vulnerable or non-vulnerable area, which may be critical in establishing how the State assesses leaching potential (Component 5). In cases of misuse, enforcement actions should be pursued.

- Describe the State's response policy regarding contaminated ground water that is used as a source of drinking water. The SMP must discuss generally what steps will be taken to protect public health. The State may need to provide or fund interim sources of drinking water if necessary. If the contamination constitutes a violation of the SDWA regulations[1] for which the Public Water System is responsible, these detections should be referred for enforcement action under authority of SDWA. The State will also need to determine actions for responding to contamination in private wells, including notifying well owners.

- The requirements listed above should be presented in the form of a general corrective response scheme, including timeframe(s) and identification of the agencies responsible for various activities, thereby illustrating the State's capacity for timely, coordinated response to contamination.

In addition to the Generic Plan Criteria listed above, a Pesticide Plan must:

- Indicate the levels (at the MCL or other reference point, or above these standards) at which the State intends to take or require remedial action to reduce contamination of currently used or reasonably expected sources of drinking water. The SMP must also indicate what specific steps the State will take, and the timeframe in which it will act, to initiate measures commensurate with contamination levels to reduce the possibility of further contamination toward significant health or environmental concern (i.e., levels at the reference point).

The response measures presented in this chapter are ideas that States should evaluate and implement as appropriate given the specific goals and conditions in each State and the guidelines presented in Appendix A. Examples are provided to encourage States that do not have a response plan in place to seek information from other States and develop their own most appropriate response strategies. This chapter discusses several aspects of response plans, including:

- How the response, monitoring, and prevention components of an SMP are related;

- An overview of selected response measures for ground water contamination;

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[1] A violation under the SDWA relates to the average contaminant concentration over four consecutive quarters or to a single sample that is greater than 4 times the MCL.

- How to evaluate the causes of pesticide contamination of ground water; and

- A framework for using reference points or action levels in implementing response measures.

6.1 Relation of Response, Monitoring, and Prevention Components of an SMP

Response measures overlap monitoring and preventive measures at the point that pesticide contamination is found in ground water. If a State discovers that contamination of ground water has occurred, then appropriate monitoring is needed (see Chapter 5). A State should also implement additional, more stringent preventive measures to prevent contamination (See Chapter 4). Evaluation monitoring should then be continued to assess the impacts of preventive measures on ground water quality (See Chapter 5).

Following detections of pesticides in ground water, appropriate response measures might include:

- Providing alternate safe sources of drinking water;

- Increasing monitoring and other activities to determine and evaluate the causes of contamination and the effectiveness of prevention or response actions;

- Implementing more stringent preventive measures, including regulatory and enforcement approaches, to eliminate the threat of further ground water contamination; and

- Remediating contaminated ground water.

6.2 Response Measures

Any confirmed detection of a pesticide in ground water should trigger a response action. Appropriate response plans depend on the level of contamination confirmed in ground water in relation to established reference points, the State's ground water protection philosophy, and the use and value of the ground water resource as well as social and economic values. Response measures might include:

- Implementing increasingly stringent preventive measures, including pesticide-use limitations or restrictions;

- Treating contaminated drinking water supplies; and

- Remediating the aquifer.

6.2.1 Implementation of Increasingly Stringent Preventive Measures

SMPs should emphasize prevention of adverse effects to human health and protection of the environmental integrity of ground water resources. Detections of pesticides in ground water serve as a means to define failure of preventive measures already taken.

Both Generic and Pesticide SMPs should consider contingency response measures for increasingly stringent prevention actions when contamination levels rise. Such measures might include the following:

- Revising pesticide management preventive measures;
- Implementing site-specific use restrictions;
- Implementing use restrictions for large, vulnerable areas; and
- Implementing statewide use restrictions or prohibition.

Before a State reassesses and revises its preventive measures, the State should consider investigating the cause(s) of a pesticide contamination incident. In particular, an investigation should seek to determine if contamination occurred as a result of normal, registered use of the pesticide or from misuse. If the contamination occurred as a result of normal, registered use, then the State should reconsider the preventive component of its SMP. Revisions to the SMP's prevention component should be tailored to the causes and level of contamination.

Limitations on pesticide use can be an effective tool to protect against the adverse effects of pesticide contamination of ground water. As discussed in Chapter 6, use limitation can apply both to application techniques and to geographic settings. If pesticides are found in ground water, actions should be taken to diagnose the cause of the particular detection to determine whether any further regulatory management approaches are needed. The most stringent and most protective preventive measure is a moratorium on pesticide use in a particular area of the State that is susceptible to ground water contamination.

6.2.2 Water Supply Treatment and Other Response Mechanisms

In addition to preventing pesticide contamination of ground water with the potential to pose risks to human health and the environment, the SMP should discuss the situations in which a State will select water supply treatment as a response measure. This decision is typically made based on the use and value of the ground water resource and the treatment techniques available (i.e. bottled water or connection to an uncontaminated water system). A State should also consider the use of alternative water supplies, depending on the risks posed by the pesticide contamination.

The use of alternative water supplies to respond to contamination incidents includes connecting to a neighboring water supply system, hauling water from a neighboring water supply system via tank trucks, and distributing bottled water. The use of alternative water supplies may be a short-term solution. Some communities, however, may need to establish permanent connections with neighboring water suppliers depending on the severity of the contamination.

The most common short term response to contaminated private drinking water supplies uses "point-of-use" (at the tap) or "point-of-entry" (entry point to the residence) water-supply treatment. Typically, this approach involves the installation and maintenance of filters that will reduce contaminant concentrations down to acceptable levels. This alternative provides treatment of the water prior to use or consumption, but does not correct the source of contamination. That is, water supply treatment does not address the environmental impacts of pesticide contamination.

Common municipal treatment processes include disinfection, filtration, coagulation, sedimentation, adsorption, blending, ion exchange, gas stripping, and membrane separation. The point-of-use activated carbon adsorption process is the most common treatment method used in individual domestic households to remove organic ground water contaminants. The efficacy and design of any water supply treatment system to remove pesticide residues should include a treatability study.

All water supply treatment schemes require maintenance. Failure to provide adequate maintenance will lead to incomplete removal of contaminants in the treatment system. Common treatment methods, such as activated carbon units, can provide an environment for microorganisms to colonize and grow. If such bacteria grow and are not removed by subsequent treatment (e.g., chlorination), an additional risk may be introduced by using the treatment system.

The State of Florida has issued policies defining action levels for filter installation and removal. In most cases, the registrants of the pesticides detected in Florida's ground water are responsible for implementing the filter programs. For additional information on the registrant-sponsored filter programs in Florida, contact the Florida Department of Environmental Protection, 2600 Blair Stone Road, Tallahassee, Florida 32399-2400; Telephone: (904)488-3601.

Registrant-sponsored filter programs have also been undertaken in **New York, Maine, and Wisconsin**. In some cases, the registrants have established the action levels at which filters should be installed or may safely be removed. State-specific legislation should be examined to identify the responsibilities of registrants, pesticide users, and State agencies in implementing and administering filter programs.

The **City of Fresno, California** is implementing a Water Quality Improvement Plan to address 1,2-dibromo-3-chloropropane (DBCP) contamination of the principal water supply. The entire water supply for the City of Fresno is derived from 267 wells that tap an EPA-designated sole-source aquifer. Seventy-one (71) of these wells have exhibited detectable levels of DBCP, and 25 were closed due to DBCP contamination that exceeds the MCL. The Water Quality Improvement Plan authorized direct DBCP mitigation measures, including wellhead treatment projects, well rehabilitation projects, the construction of replacement wells, and the construction of water main extensions to provide clean water supplies. To date, the City has expended over $50 million to address ground water contamination problems associated with DBCP. Because of DBCP's half life and the persistent migration of this contaminant into aquifer areas that supply the city's drinking water, the City of Fresno estimates that mitigation and litigation costs will exceed $200 million dollars by the year 2000. For additional information, contact Martin McIntyre, City of Fresno Water Division, 1910 East University, Fresno, CA 93703; Telephone: (209) 498-4126.

6.2.3 Remediation

The SMP should discuss the situations in which remediation will be selected as a response measure, and the remediation techniques that will be considered. In some instances, particularly those where ground water contamination is attributable to point-source releases of pesticides (e.g., releases from pesticide storage sites), containment measures and/or subsurface restoration techniques may be appropriate. The following sections provide an overview of containment and restoration measures that may be pertinent in cases of high-level, localized pesticide contamination of ground water.

The **California Regional Water Quality Control Board** conducted a study of alternative mitigation strategies for contaminated ground water in the San Joaquin Valley. More than 112 public water-supply wells in four counties are reported to be shut down due to DBCP concentrations that exceed the MCL of 0.2 ppb. The preliminary results of the study include the development of BMPs to address the mitigation of DBCP contamination of ground water, an economic evaluation of DBCP mitigation alternatives, an evaluation of the feasibility of implementing a ground water extraction/recharge procedure to reduce DBCP concentrations in the San Joaquin Valley, and a viable plan for DBCP mitigation in the area. For additional information, contact the California Regional Water Quality Control Board, 3443 Routine Road, Suite A, Sacramento, CA 95827; Telephone: (916) 255-3000.

Vertical Flow Source Barriers

For relatively small source areas (point sources), preventing the vertical recharge of water would tend to isolate residual contamination in the unsaturated zone. This could be accomplished by placing an impermeable barrier on the surface, which could be either a natural clay material or a synthetic liner. The cost of this containment method would generally restrict such practices to small contaminated areas.

Hydraulic Withdrawals

Hydraulic withdrawals are commonly used in response to point source contamination. Two common types of hydraulic withdrawals have application for pesticide contamination: abstraction wells and drains. Abstraction wells are sometimes used to control contaminant migration and as a method to remediate contaminated aquifers (Keely, 1989; Mercer et al., 1990). The notion is simple: by placing a well in a contaminated region and pumping water out of the well, ground water flows in every direction toward the well. If the well, or system of wells, pumps at a sufficient rate, a contaminant plume can be contained.

Hydraulic withdrawals are sometimes achieved through the use of drains. In drainage systems, a drain is placed at the boundary of a contaminated region at a depth sufficient to ensure the capture of all contaminated water. This differs from a well containment system in that water is removed along a line rather than at a point. The practical significance of this difference is that contaminant containment can often be achieved with less total water being removed from a system using a drain than an abstraction well or series of abstraction wells. This leads to a reduction in the volume of contaminated water that requires treatment or disposal.

Physical Removal and Disposal

Physical removal and disposal of contaminated source materials is required under unusual circumstances. Typically, the source of contamination may be isolated to a small area. Such measures are typically very expensive and should be used only as a last resort. The high cost of physical source removal and disposal enforces practical limits on the method to relatively small (point source), highly contaminated regions that are affected by solutes that are relatively resistant to degradation. This would not be a feasible alternative for nonpoint source pesticide contamination incidents.

Enhanced Degradation

The rate at which pesticides degrade in the subsurface environment depends on many factors. In response to subsurface contamination, a pesticide's propensity to degrade may be exploited in the source area to limit the solute mass that will reach the saturated zone. Two classes of enhanced degradation are discussed: abiotic degradation and biodegradation.

Many pesticides undergo abiotic degradation by chemical hydrolysis, which is usually a second-order reaction in which the degradation rate depends upon the concentration of the solute and the pH of the system. Information about hydrolysis reactions is often available from pesticide manufacturers. Both acid- and base-catalyzed hydrolysis reactions are common for certain classes of pesticides. If subsurface contamination exists with a pesticide that undergoes acid-catalyzed hydrolysis, lowering the pH in the unsaturated zone of the source area would enhance the natural degradation rate of the contaminant source. For such a case, lowering the pH by one unit would increase the rate of degradation by a factor of 10; lowering the pH by two units would increase the rate of degradation by a factor of 100 and similarly for other pH changes. The reverse approach---raising the pH---would be appropriate for regions contaminated with a pesticide that undergoes base-catalyzed hydrolysis.

Nebraska's approach to a number of ground water contamination incidents attributed to the use of carbon tetrachloride at grain storage sites provides an example of a range of response actions. Seven sites in Nebraska were identified as having contamination levels that significantly exceeded the MCL of 5 ppb for carbon tetrachloride. The following response activities have been initiated at these sites:

- One site, in Waverly, Nebraska, was placed on the National Priority List due to the level of contamination (3120 ppb carbon tetrachloride) in one water-supply well. Under the Superfund program, ground water remediation using soil-vapor extraction and pump-and-treat technology is being undertaken to remove the carbon tetrachloride contamination.

- One well in Bruno, Nebraska, was found to have carbon tetrachloride contamination above the MCL, but other nearby wells do not exhibit contamination. Water from the contaminated well is being blended with water from uncontaminated wells to bring the combined waters within the drinking water standard. USDA plans to reimburse Bruno for part of the cost of replacing the contaminated well.

- As an interim measure, EPA has provided bottled water to the communities of Bruno and Walton, Nebraska, during studies to rectify the problem of contaminated drinking-water supplies.

- USDA sponsored ongoing studies at Murdock, Nebraska, to evaluate the extent of the carbon tetrachloride plume. The contaminated well has been replaced with a larger, deeper well, and the nearby residents have formed a rural water district to manage the new well and water supply.

- EPA has identified 70 communities in Nebraska with private wells that are located in the vicinity of grain storage bins. Outreach efforts are being planned to communicate the risks and issues surrounding possible carbon tetrachloride contamination of private wells.

Many pesticides are degraded by microorganisms that may grow in the subsurface environment. Encouraging biodegradation of a pesticide from a contaminant source zone is a feasible response to limit the source mass that may contaminate the saturated zone. In general, enhanced biodegradation is based upon an understanding of conditions that favor the growth of an appropriate microbial community and the consumption of the contaminant. A thorough understanding of pesticide characteristics and laboratory experimentation with site materials would normally be required to guide an enhanced bioremediation effort. Factors that may enhance remediation are: seeding an appropriate microbial community; supplying an electron acceptor, e.g., oxygen; providing nutrients to the microbial community, such as nitrogen, phosphorus, trace elements, or vitamins; adjusting the moisture content in the unsaturated zone; or elevating the temperature of the media.

Although the CERCLA program only infrequently addresses issues of pesticides in ground water at remedial action sites, techniques such as ground water extraction to address volatile organic compounds have been widely used and analyzed at Superfund sites. A number of published analyses of these techniques are available in OERR (HSCD) 1989.

6.3 Determination and Evaluation of Contamination Causes

At a minimum, confirmed detections of a pesticide in ground water need to be treated as a cause for concern, and should trigger some action to diagnose the cause of the particular detection and determine whether any further regulatory/management approaches are needed. From a management perspective, this means a determination of the circumstances that led to the contamination of ground water. Of primary concern is the determination of whether or not contamination occurred as a result of normal, registered use of the pesticide, or from misuse.

> Some States have involved the registrants of pesticides that have been detected in ground water in the evaluation process. **The State of Florida** requires registrant participation that includes funding of investigations, ground water sampling activities, and chemical analysis of well-water samples.

Evaluation of the extent of the contamination, and its causes includes characterizing the contamination in space and time and predicting the ground water contamination resulting from continued contribution of pollutants. Characterization of a contamination incident requires knowledge of the nature of the solute source (e.g., mass of pesticide spilled, or application rate used), rates of degradation, volatilization, uptake, sorption, leaching, and ground water flow. Several of the vulnerability assessment methods discussed in Chapter 3 may be useful in evaluating contamination extent and causes.

Monitoring is also an integral part of the investigation of ground water contamination causes. Chapter 5 presents information on the development of monitoring plans in response to detections of pesticides in ground water.

California has also established a process for responding to low-level residues of pesticides found for the first time, in California's ground water. The process focuses on the following steps:

- Gathering information on the contamination site;
- Evaluating the extent of contamination and potential contamination sources by conducting monitoring in the section where contamination was confirmed and in the sections adjacent to the detection site;
- Assessing whether or not the residues resulted from legal use. If the use was legal the registrant must request a hearing within 30 days of notification of the detection in order to avoid cancellation of the pesticide;
- If appropriate, modifying the use of pesticides to prevent further contamination of ground water; and
- Conducting monitoring and field studies to evaluate the effectiveness of response actions.

Based on the response evaluations, the Director of the California Department of Pesticide Regulation may establish Pesticide Management Zones (PMZs). These PMZs function as chemical-specific areas identifying those areas that are sensitive to the migration of pesticide residues in ground water. The use of specific pesticides is restricted in these areas. In order to use a chemical in its PMZ, users are required to obtain a special permit from the local County Agricultural Commissioner. To get such a permit, users must submit a ground water protection advisory written by a licensed Pest Control Advisor who has completed Department-approved ground water protection training in the previous 2 years. In addition, monitoring is conducted adjacent to the PMZ to determine whether or not additional areas should be designated for PMZs. If a pesticide that was previously subjected to the California response process is again found in ground water, and it is determined that the residues result from legal agricultural use, then a new PMZ is created. For additional information on the California response process, contact the California Department of Pesticide Regulation, Environmental Monitoring and Pest Management Branch, 1220 N Street, Sacramento, California 95814.

6.4 Use of Reference Points or Action Levels

States will need to identify how to respond to contamination of current or reasonably expected drinking water from public or private wells before exceeding the established MCL. States are encouraged to establish action levels at fractions of the federal enforcement standards (MCLs or HAs). Ground water contamination should then be evaluated with respect to these action levels to determine the stringency of response actions.

Whenever evidence indicates an increased risk that ground water contamination is approaching or may reach or exceed the reference point or action level, the stringency of response measures should increase in the contaminated area, and the stringency of preventive measures should increase in areas of similar vulnerability. In addition, States should describe the factors and rationale considered in choosing the action levels and the preventive and response measures. In effect, EPA encourages States to develop graduated or hierarchical approaches whereby increasingly stringent response measures will be instituted as levels increase. States are always free to respond more aggressively to any level of detection in accordance with their ground water protection philosophies and on the basis of vulnerability assessments, analyses of pesticide usage, and determination of ground water use and value. Figure 6-1 presents a range of response measures that can be implemented as pesticide detection levels in ground water approach the reference point.

In general, a State should consider the following activities in determining its response plan:

- Confirming detections and determine the extent of contamination;
- Responding to confirmed detections that are below these reference levels; and
- Responding to confirmed detections that are at or above these reference levels.

6.4.1 What is Detection?

Detection is generally said to occur when the presence of a designated constituent is found in ground water. Detection occurs by monitoring for specific pesticides and/or their reaction products. The presence of contamination should include an analysis to measure if the constituent concentration is significant given the method detection limits (MDL) and the spatial and temporal variation of the constituents in ground water.

The method detection limit is the minimum concentration of the designated pesticide or reaction product measured and reported with a specified confidence (usually 99 percent) that the concentration is above zero. It is an analytical chemistry concept. As Chapter 5 discusses, practical quantitation limits (PQLs) are often set at 10 times the analytical MDL and, as the name implies, it is the level at which quantitation of the designated pesticide or reaction product is practical. Strictly speaking, a detection occurs anytime a concentration above the MDL is determined in the analytical laboratory. In cases where MDLs are near the health or regulatory levels, any concentration above the MDL would be cause for concern. In other instances when the analytical MDL is much lower than any of the levels of health or regulatory concern, the PQL can be used

Figure 6-1. Range of Technical Tools for Developing a Response Plan

	Type of Response Action	Implementation of Increasingly Stringent Preventive Measures	Implementation of Water Supply Treatment Programs	Implementation of Ground Water Remediation Techniques
▲	• Implement remediation activities		• Provide alternative sources of drinking water	• Initiate ground water remediation activities
		• Prohibit the use of a pesticide in specified areas		
	• Implement more stringent preventive measures	• Institute additional limitations on pesticide application techniques and geographic settings	• Implement treatment for private water wells • Implement treatment techniques for pesticides for public water supplies	
Reference Point ▲	• Implement treatment techniques for public and private water supplies	• Limit pesticide application techniques and geographic settings		
	• Implement additional preventive measures	• Provide assistance for Integrated Pest Management • Implement water well requirements	• Provide technical assistance to rural well owners and operators • Provide technical assistance to local public water systems	
No Detection	• Implement initial preventive measures	• Implement pesticides handling, storage, and disposal requirements		

as the reporting limit. Only levels determined to be above that limit are considered detections.

In general, one of the following events constitutes confirmation of pesticide contamination:

- Detection;
- Detection at a level of concern (i.e., the MCL); or
- Qualitative determinations of presence at some level.

The level of confirmation may involve field and/or laboratory analyses.

6.4.2 Responding to Detections Below the MCL or HA

Detections of pesticides in ground water that are well below established MCLs or HAs provide the widest range of response options. If pesticide contamination is found to originate from a point source (e.g., spill) or from direct contamination of ground water (e.g., improper well abandonment), then a State may consider implementing more stringent measures that will prevent these types of point source contamination (See Section 4.2.1). If nonpoint source contamination is suspected, then more stringent preventive measures, described in Sections 4.2.2 and 4.2.3, should be considered. Depending on ground water use and value characteristics and social and economic values, appropriate response measures may range from voluntary or education-based approaches to more stringent regulatory approaches. Continued or increased monitoring efforts are an integral part of response actions for low-level detections. Monitoring may enable States to both evaluate potential causes for the contamination and assess the effectiveness of response actions.

As levels of confirmed contamination approach the reference level, response measures should become more stringent in their control of pesticide use. Special restrictions on pesticide use in sensitive areas, permitting, area restrictions, or use prohibitions are among the approaches that States should consider in response to escalating levels of contamination.

It should be recognized that there are substantial scientific limitations at this time in the State of the art of both monitoring and mathematical modeling to predict the behavior of pesticide residues in the subsurface environment. Consequently, a graduated approach to pesticide management may not always be a practical possibility. Also, pesticide levels detected in ground water have been known to fluctuate substantially over relatively short periods of time. For example, a heavy rainfall can cause such fluctuation. Thus, a detection at levels well below the MCL or reference point will not always offer assurance that there is time for a gradual escalation of preventive measures in order to prevent contaminant concentrations from reaching the MCL. Another relevant factor is that for some pesticides the MCL or health advisory level is quite low in relation to the limits of analytical detection. In such cases, a positive detection may be so close to the MCL that it would justify very stringent response measures.

Wisconsin's Generic Ground Water Rule provides that if a pesticide is found in ground water in Wisconsin, the Department of Agriculture, Trade, and Consumer Protection will investigate the incident to determine the following:

- Whether the presence of the pesticide resulted from a violation of a existing statute, rule, or order; and
- Whether the concentration attains or exceeds an enforcement standard or preventive action limit.

If the presence of the pesticide resulted from misuse, even if the concentration does not exceed an enforcement standard or prevention action limit, the Department may proceed by following one of its enforcement options.

Whether or not a pesticide residue results from a violation of a statute or rule, if the pesticide concentration exceeds an enforcement or preventive action limit, the State of Wisconsin may implement any one or combination of "site-specific responses," including:

- Prohibitions against the use of a pesticide;
- Limitations on the purposes for which a pesticide may be used;
- Limitations on the rate at which a pesticide is applied;
- Limitations on the time and frequency of pesticide use;
- Limitations on the method of pesticide use; and
- Requirements for the training or certification of pesticide applicators or other persons.

For additional information on the Wisconsin Generic Ground Water Rule, contact the Wisconsin Department of Agriculture, Trade, and Consumer Protection, 801 West Badger Road, Post Office Box 8911, Madison, Wisconsin, 53708-8911.

6.4.3 Responding to Detections At or Above the MCL or HA

Detections of pesticides in ground water that are at or above established MCLs or HAs signify the failure of the SMP. If the contamination is detected within a public-water supply at a level above the MCL, the contamination also constitutes a violation of the SDWA. Although SDWA regulations do not apply to private wells, most States use these or similar standards as a basis for informing well owners of health risks. Some State laws also require closure of private wells that do not meet drinking-water standards. As a minimum, States should respond to high-level detections of pesticides in ground water by notifying the affected users of the ground water resource and by providing alternative supplies of safe drinking water.

6.5 References

Keely, J.F. 1989. Performance Evaluations of Pump-and-Treat Remediations. U.S. Environmental Protection Agency, Ground Water Issue. EPA 540/4-89/005. 19 pp.

Maine Board of Pesticide Control. 1990. Proposed Pesticides in Ground Water Management Plan. 92 pp.

Mercer, J.W., D.C. Skipp, and D. Giffin. 1990. Basics of Pump-and-Treat Ground Water Remediation Technology. U.S. Environmental Protection Agency, Office of Research and Development. EPA 600/8-90/003. NTIS PB90-274549. 67 pp.

U.S. EPA, Office of Emergency Response and Remediation. 1988. Guidance on Remedial Actions for Contaminated Ground Water at Superfund Sites. EPA 540/g-88/003. 180 pp.

U.S. EPA, Office of Emergency Response and Remediation. 1989. Determining Soil Response Action Levels Based on Potential Contaminant Migration to Ground Water: A Compendium of Examples. EPA 540/2-89/057. 145 pp.

U.S. EPA, Office of Emergency Response and Remediation (HSCD). 1989. Evaluation of Ground Water Extraction Remedies, Volume 1: Summary Report. EPA 540/2-89/054. 65 pp.

U.S. EPA, Office of Emergency Response and Remediation (HSCD). 1989. Evaluation of Ground Water Extraction Remedies, Volume 2: Case Studies 1-19 (Interim Final). EPA 540/2-89/054b. 557 pp.

U.S. EPA, Office of Emergency Response and Remediation (HSCD). 1989. Evaluation of Ground Water Extraction Remedies, Volume 3: General Site Data, Data Base Reports (Interim Final). EPA 540/2-89/054c. 121 pp.

U.S. EPA, Office of Research and Development and Office of Emergency Response and Remediation. 1990. Remediation Completed: But is the Ground Water Meeting the Safe Drinking Water Act Requirements? EPA 600/d-90/089. NTIS PB90-272576. 22 pp.

Chapter 7

Sources of Technical Information

State and local agencies can be important sources of technical information for SMPs. Input from State agriculture, geology, water quality, and health agencies is critical to the development of SMPs. Several federal agencies and other national centers can also provide useful technical information to States. Although many of the federal sources are located near Washington, D.C., there are numerous organizations operating at the State or local levels that act as clearinghouses for technical information. For example, the USDA maintains State and local offices for the Soil Conservation Service and the Agricultural Stabilization and Conservation Service.

In addition to the contacts listed below, the National Technical Information Service (NTIS) is a central source for the public sale of technical and nontechnical information that is published by U.S. and foreign government agencies. The information available from NTIS includes research, development, engineering, and business reports. When ordering a document from NTIS, it is useful to reference the document's unique NTIS number (NTIS number for many EPA documents begin with PB). NTIS document numbers may be obtained through NTIS's *Government Report Announcement and Index* (published annually and twice a month), the online NTIS Bibliographic Data Base, or NTIS's Identification Department.

NTIS
5285 Port Royal Road
Springfield, VA 22161
(703) 487-4650 (to order documents)
(703) 487-4780 (NTIS Identification Department)

NCEPI
11029 Kenwood Road
Building 5
Cincinnati, OH 45242
(513) 569-7980

CERI
26 West Martin Luther King Drive
Cincinnati, OH 45268
(513) 569-7562

EPA's ACCESS EPA System (NTIS document number for 1992 edition: PB92-147438) provides access to EPA's environmental information. The document consists of seven chapters that list and describe environmental information available from EPA. Selected EPA documents may be ordered from the following sources:

- EPA National Center for Environmental Publications and Information (NCEPI) - clearinghouse for scientific/technical and public-oriented environmental information that is published by EPA; and

- EPA Center for Environmental Research Information (CERI) - clearinghouse for scientific/technical and public-oriented environmental information that is supported by EPA's Office of Research and Development (ORD).

Some of the U.S. government publications listed in the reference sections at the end of each chapter include NTIS and/or EPA document reference numbers.

Chapter 7 is organized into eight sections. Section 7.1 identifies the SMP components where technical information will be useful to States and the categories of information that States may need to develop these components. Sections 7.2 through 7.6 discuss the information maintained by the federal agencies and national research centers that address pesticides and/or ground water-related issues. Section 7.7 provides contacts for obtaining the information presented in this chapter. Section 7.8 provides selected references.

7.1 Categories of Technical Information

Technical information from outside sources will be useful to States that are developing the following components of their Generic or Pesticide SMPs:

- Basis for Assessment and Planning (component 5);
- Monitoring (component 6);
- Prevention Actions (component 7); and
- Response to Detections of Pesticides (component 8).

To develop these SMP components, States need the following categories of information:

- **Pesticides**. Product information on specific pesticides and estimates of the use of these pesticides at a State or sub-county level.

- **Hydrogeology**. Guidance materials and technical assistance to assess risks to States' ground water resources, including characterizing the vulnerability of ground water to contamination. Existing compilations of hydrogeologic data.

- **Water Quality**. Drinking water MCLs and HAs as well as State water quality standards. Guidance materials and technical assistance for monitoring ambient water quality.

- **Public Health and Ecosystems**. Research reports on health risks posed to humans resulting from exposure to pesticides. Research report on the impacts of pesticides on ecosystems.

- **Fate and Transport Information and Models**. Guidance, technical assistance, research reports that address occurrence (including levels), movement, and quality of ground water in relation to the occurrence, quantity, and movement of pesticides. Tools for modelling the relationships between pesticide use and ground water quality.

- **Agricultural Practices**. Guidance materials, education programs, and research reports on the impacts of agricultural practices on ground water quality.

- **Conservation Implementation and Cost-Sharing**. Technical assistance and outreach programs for implementing agricultural practices (e.g., contour plowing, filter strips, etc.) that reduce the impacts of pesticides on ground water quality from pesticide leaching or runoff.

- **Alternative Technology**. Technical assistance, outreach programs, and research reports for implementing agricultural practices (e.g., low input sustainable agriculture) that reduce the use of pesticides.

Table 7-1 provides a summary of the national research centers, programs, data bases, agency bureaus, and key studies for selected federal agencies that are sources of information for one or more of the information categories.

Sections 7.2 through 7.5 provide a further description of the information available from the U.S. Environmental Protection Agency, U.S. Department of Interior, U.S. Department of Agriculture, and National Oceanic and Atmospheric Administration, respectively. Section 7.6 discusses information maintained by research centers associated with nonprofit organizations or government trusts. Readers can obtain information presented in Sections 7.2 through 7.6 by using the list of contacts found in Section 7.7. Section 7.8 provides a list of selected references useful for the development of SMPs.

7.2 Sources of Information from the U.S. Environmental Protection Agency (EPA)

EPA's Office of Water and Office of Information Resources Management have released a document entitled Office of Water Environmental and Program Information Systems Compendium: Fiscal Year 1990, which covers most major information systems within EPA as well as important sources in other Federal agencies (U.S. EPA, 1990). Additional references may be found in an Office of Technology Assessment report on agrichemical issues (OTA, 1990) and an Office of Ground Water Protection[1] (U.S. EPA, 1988) study on agricultural management practices for pesticide pollution control. In addition, several specific EPA information sources are discussed in the following subsections.

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[1] EPA's Office of Ground Water Protection is now the Ground Water Protection Division in the Office of Ground Water and Drinking Water. Documents are identified according to the name of the organization at the time the document was published.

Table 7-1. Selected Sources of Information

SOURCES	INFORMATION CATEGORIES							
	Pesticide Product Info.	Hydro-geology	Water Quality	Public Health & Ecosystems	Fate & Transport Models	Agricul-tural Practices	Conserva-tion & Cost-Sharing	Alternative Technology
U.S. Environmental Protection Agency								
National Pesticide Survey			✓	✓		✓		
Pesticide Information Network	✓		✓	✓	✓			
National Estuarine Program		✓	✓	✓	✓	✓	✓	
Pesticide Information Network	✓		✓	✓	✓			
Pesticides in Ground Water Data Base			✓	✓				
Comprehensive State Ground Water Protection Program		✓	✓		✓			✓
Nitrogen Action Plan					✓	✓	✓	
Agriculture Pollution Prevention Strategy					✓	✓	✓	
Clean Water Act Programs			✓			✓		
Safe Drinking Water Act Programs		✓	✓	✓	✓	✓	✓	
STORET			✓					
FRDS			✓					
ORD Ground Water Research Program		✓	✓	✓	✓	✓		
Special Toxicity Data Bases				✓				
U.S. Department of Interior								
U.S. Geological Survey		✓	✓					
U.S. Fish and Wildlife Service			✓	✓				
U.S. Department of Agriculture								
Agricultural Stabilization & Conservation Service							✓	
Agricultural Research Service					✓			

Table 7-1. Selected Sources of Information (continued)

SOURCES	INFORMATION CATEGORIES: Pesticide Product Info.	Hydro-geology	Water Quality	Public Health & Ecosystems	Fate & Transport Models	Agricul-tural Practices	Conserva-tion & Cost-Sharing	Alternative Technology
Cooperative State Research Service and State Agricultural Experiment Stations	✓	✓	✓	✓	✓	✓	✓	✓
National Agricultural Pesticide Impact Assessment Program	✓							
Cooperative Extension Service	✓					✓		✓
Economic Research Service/National Agricultural Statistics Service	✓							
Forest Service	✓	✓	✓			✓		
Soil Conservation Service		✓				✓	✓	✓
National Oceanic & Atmospheric Admin.								
National Coastal Pollutant Discharge Inventory			✓	✓				
Coastal Zone Management Act		✓	✓	✓		✓	✓	✓
Other Sources								
Institute for Alternative Agriculture								✓
Land Stewardship Project								✓
Conservation Technology Information Center	✓					✓		✓
TVA/National Fertilizer and Environment Research Center	✓					✓		✓
National Pesticide Information Retrieval System	✓							
Fish and Wildlife Information Exchange				✓				
National Center for Food and Agricultural Policy	✓							

7.2.1 National Survey of Pesticides in Drinking Water Wells

Early in 1992 the EPA Office of Ground Water and Drinking Water and the Office of Pesticide Programs completed a joint multiyear national survey of pesticides in drinking water wells. Between 1988 and 1990, EPA sampled 1,349 community water system wells and rural domestic wells for the presence of 101 pesticides, 25 pesticide degradates, and nitrate (127 total analytes). In Phase I, completed in November 1990, EPA developed national estimates of the frequency and concentration of pesticides and nitrate present in drinking water wells in the United States. The Phase II report, issued in January 1992, analyzed the NPS data alone and in combination with pertinent data from non-national pesticide survey sources. This report investigated how the presence of pesticides and nitrate in drinking water wells might be associated with patterns of pesticide use, the sensitivity of areas surrounding drinking water wells to ground water contamination, transport of chemicals to well water, and other factors, including pesticide chemistry and the physical condition of drinking water wells.

The Phase I Report provides a detailed summary of the survey design, survey implementation, analyte selection and analysis, quality assurance/quality control procedures, and national estimates of the occurrence and frequency of detections of pesticides and nitrate in drinking water wells. The Phase I Report also includes detailed appendices on statistical design, survey implementation, tabulations of data, and copies of the survey questionnaires.

The National Pesticide Survey Phase II Report discusses the statistical approaches followed in the Phase II studies and provides results of analyses involving a broad range of data sources. It also provides recommendations for future studies.

In addition to the National Pesticide Survey Phase I Report and Phase II Report, the survey also produced eight multiresidue chemical analytic methods, quality assurance plans, training materials and protocols for well sampling and sample handling, fact-sheets, health advisories, health advisory summaries, and a number of data files. Copies of many of these materials or access to data can be obtained through the National Technical Information Service or the EPA Office of Pesticides Programs Docket.

7.2.2 Pesticide Information Network (PIN)

Pesticide Information Network is a collection of files containing up-to-date pesticide information and is maintained by EPA's Office of Pesticide Programs. Located on a personal computer, PIN is accessible by dataphone similar to a PC-to-PC bulletin board. Files currently available through PIN are:

- The ***Pesticide Monitoring Inventory*** containing information on pesticide monitoring projects performed by federal, State, and local governments and private institutions;
- The ***Restricted-Use Products File*** containing a comprehensive list of all pesticide products that have been classified as Restricted-Use

Pesticides under 40 CFR Part 152, Subpart I. This file is updated monthly; and

- The ***Chemical Index*** containing a list of all chemicals contained in the Pesticide Monitoring Inventory and Restricted-Use Products File. All chemicals are cross-referenced to synonyms and Chemical Abstracts System (CAS) numbers.

7.2.3 Pesticides in Ground Water Data Base (PGWDB)

The PGWDB is a collection of ground water monitoring studies conducted by federal, State, and local governments, the pesticide industry and private institutions. The PGWDB consists of monitoring data and auxiliary information in both computerized and hard-copy form. The PGWDB provides an overview of the ground water monitoring efforts for pesticides in the United States, pesticides that found in the nation's ground water, and the areas of the country that appear vulnerable to pesticide contamination. The computerized portion of the PGWDB will become a part of the PIN in 1993.

7.2.4 Comprehensive State Ground Water Protection Program (CSGWPP)

CSGWPPs are the focal point for a new partnership between EPA, the States, Native American Tribes, and local governments to achieve a more efficient, coherent, and comprehensive approach to protecting the nation's ground water resources. CSGWPPs are an important step in implementing EPA's ground water protection goals and principles. EPA is seeking to make the Comprehensive Program approach the catalyst for fundamental change in the development and implementation of ground water protection programs at the federal, State, and local levels. A CSGWPP consists of the following six strategic activities: (1) establish goal; (2) establish priorities, based on characterization of the resource, identification of sources of contamination, and programmatic needs; (3) define roles, authorities, responsibilities, resources, and coordinating mechanisms; (4) implement necessary activities; (5) collect and manage information; and (6) ensure public participation. The Strategic activities foster more efficient and effective ground water protection through more cooperative, consistent, and coordinated operation of all relevant federal, State, and local programs within a State.

7.2.5 Nitrogen Action Plan (NAP)

The Nitrogen Action Plan is the result of EPA strategic planning and involves the coordination of a number of EPA offices in order to protect ground water and surface water from all sources of contamination by nitrate and related nitrogen compounds through pollution prevention. Currently, the NAP is in the planning and development stages. Once operational, the NAP will provide technical assistance and educational support to promote the reduction of fertilizer use and to improve the control of runoff and infiltration from livestock operations.

7.2.6 National Estuarine Program (NEP) and Chesapeake Bay Program

The Chesapeake Bay Program is the exemplar for over a dozen estuarine studies under the NEP defined in the Clean Water Act's Section 320. These estuarine studies conduct assessments of toxics impacts from both point and nonpoint sources, including possible inputs to the estuarine systems from ground water. Protection or remediation strategies defined under the NEP's Comprehensive Conservation and Management Plans could be useful components for inclusion in Pesticide SMPs.

7.2.7 Clean Water Act Programs

The objective of the Clean Water Act is to restore and maintain the chemical, physical, and biological integrity of the nation's waters. Several Clean Water Act programs provide information useful for the development of pesticide SMPs.

- **Section 319.** State Assessment Reports and Management Plans developed under the Section 319 Nonpoint Source program provide summaries of assessment information on surface water and ground water conditions, including information on contamination from pesticides. Priority ground waters identified under this program can be used to target critical areas for SMPs. The Section 319 process has resulted in the development of sets of BMPs for use in protecting surface water quality and for remediating water-quality problems. States have outlined a series of management activities that may include projects dealing with ground water problems to promote the implementation of approved BMPs. Suitable Section 319 BMPs constitute one possible source of protection and remediation techniques for inclusion in Pesticide SMPs. Nonpoint Source Program (NPS) is a grant program which provides annual grants to States to address NPS pollution. Grant requirements are flexible, so States can address NPS problems in a prioritized fashion.

- **Section 305.** This section provides a major mechanism for States to report assessment information on the condition of their surface water and ground water supplies. EPA summarizes these biennial State submittals in a report to Congress and stores information in a data base called the Waterbody System.

- **Section 304.** Under this section of the Clean Water Act, EPA is authorized to publish and update ambient water quality criteria. These criteria provide guidance on the environmental effects of pollutants and may be useful to States in deriving regulatory requirements. The water quality criteria reflect the current scientific knowledge of the impacts of pollutants on surface water and ground water ecosystems. A document entitled "Quality Criteria for Water 1986," also referred to as the "Gold Book" contains summaries of the water quality criteria for all the contaminants for which EPA has developed recommendations, as well as a detailed description of the procedures used to derive the recommendations. This document is available through the U.S. Government Printing Office (Order No. 955-002-00000-8.) Information on new or revised water quality criteria and standards for aquatic life can be obtained from the EPA Office of Science and Technology.

- **Section 402.** The National Pollutant Discharge Elimination System (NPDES) program established under this section addresses the problem of feedlot contamination. The problems presented by feedlots frequently stem from contamination by conventional pollutants (phosphorous, nitrogen, etc.). The NPDES program will develop a permitting/enforcement guidance on feedlots that expands the focus of permits to best management practices (BMPs) including land application, manure storage, and composting.

7.2.8 Safe Drinking Water Act Programs (SDWA)

Several SDWA programs currently operating through the EPA Office of Ground Water and Drinking Water can provide support for Pesticide SMPs:

- **Public Water Supply Program.** This program establishes and enforces drinking water standards under the authority of the Safe Drinking Water Act. Maximum Contaminant Level (MCL) standards exist for 26 pesticides, nitrogen compounds, and other contaminants. In practice, the quality of the water entering the distribution system is monitored. In many cases the water has been treated and the analytical results may not reflect actual ground water quality. Treatment generally consists only of chlorination, but may also include aeration or softening. Provisions are available by which States may waive sampling requirements if certain conditions are met.

- **Wellhead Protection Program.** Established to protect public ground water supplies from contamination. States develop and implement land-use controls and other preventive measures for all sources of contamination within wellhead protection areas. The promotion of best management practices for agriculture-related sources of contamination is currently under consideration.

- **Sole Source Aquifer Programs.** Provides protection plans for selected aquifers that include a map showing the detailed boundary of the critical protection area and an assessment of the relationship between activities on the land surface and ground water quality.

- **UIC Program: Class V Wells.** Affords protection of all underground sources of drinking water from contamination by well operations. States may obtain primacy to implement the program.

7.2.9 Federal Reporting Data System (FRDS)

FRDS is an automated data base for the Public Water System Supervision Program maintained by EPA's Office of Ground Water and Drinking Water. It contains information about public water supply systems and their compliance with monitoring requirements, MCL regulations, and other Safe Drinking Water Act (SDWA) requirements. The system lists public water-supply systems by source (ground water or surface water) and by site. Contact Regional EPA offices and State SDWA lead agencies for access.

7.2.10 Storage and Retrieval of U.S. Waterways Parametric Data System (STORET)

The STORET data base is maintained by EPA's Office of Water. STORET is oriented primarily toward surface water monitoring sites. STORET also contains ground water monitoring data. The system has links to a number of other data files (e.g., the STORET Fish Kill File and BIOS for biological data) and is now being linked to sophisticated data integration and mapping systems to modernize its user interface and report writing capabilities.

7.2.11 Office of Research and Development (ORD) Ground Water Research Program

ORD offers expertise and publications in many aspects of ground water science, including the monitoring, fate, and transport of pesticides. One service provided through the ORD Ground Water Research Program is the Center for Exposure Assessment Modeling (CEAM) which provides a wide range of predictive modeling tools for water, air, soil, and multimedia assessments of organic chemicals and metals. CEAM maintains a distribution center for models and data bases. All computer programs distributed by CEAM are in the public domain and are freely available to users. For example, the Pesticide Root Zone Model (PRZM) predicts the leaching of pesticides. Examples of data bases include soils Data Base Analyzer Parameter Estimator (DBAPE) and historical weather data. A recently initiated data base, FATE: The Environmental Fate Constants Information System Data Base, provides fate parameters for pesticides.

7.2.12 Special Toxicity Data Bases

Several toxicity data bases are available to assist in the development of SMPs. These include:

- **LISTS**. An inventory of about 1,716 chemical substances regulated by EPA giving all pertinent regulatory programs with oversight over the substances and references to commonly accepted analytical techniques.

- **AQUIRE (Aquatic Toxicity Information Retrieval Data Base).** Contains aquatic toxicity information for over 5,000 chemicals and over 2,400 test species extracted from available scientific literature, including coverage for sublethal effects and bioaccumulation impacts.

- **IRIS (Integrated Risk Information System).** A data base that offers human health risk information useful in decision-making and regulatory activities involving risk assessment.

- **TRIS (Toxic Chemical Release Inventory System).** A data resource created in response to the 1986 Superfund amendments that contains extensive information on toxic chemicals stored or released in large volumes from facilities nationwide. Information on agricultural chemicals, however, is generally not included in this system.

7.3 Sources of Information from the U.S. Department of Interior

The U.S. Department of Interior includes several agencies that may provide useful technical assistance or information to States.

7.3.1 U.S. Geological Survey (USGS)

The responsibilities of the U.S. Geological Survey include investigating and assessing the nation's land, water, energy, and mineral resources. To study water, the USGS conducts nationwide assessment of the quality, quantity, and use of the nation's water resources. Information is available through the National Water Data Exchange (NAWDEX), which includes information on over 450,000 sites for which water information is available from over 400 organizations. Although NAWDEX is not a medium for the actual storage of water quality data, it does provide a convenient directory for determining if specific types of information are available. The USGS's own water quality data collections are maintained in the national Water Storage and Retrieval System (WATSTORE). NAWDEX assistance centers and data on regional water resources are maintained at each of the USGS Water Resources Division District Offices. Section 7.7, Table 7-2, provides contact information for WATSTORE and NAWDEX.

The Regional Aquifer Systems Analysis Program (RASA) has led to the development of detailed computer simulation models to define the chemical quality and discharge-recharge features of numerous major aquifer systems. The U. S. Geological Survey (USGS) also conducts the following water-resource programs:

- Federal-State Cooperative Program;

- Toxic Substances Hydrology program;

- Water-Use program;

- Irrigation/Drainage program;
- National Water Quality Assessment Program; and
- Grant support to the 54 State and Territory Water Resources Institutes.

The USGS also cooperates with local, State, and federal agencies to operate a network of streamflow gauging stations. Other relevant projects include the Mid-Continent Initiative, which has helped characterize the environmental fate of such herbicides as atrazine in ground water and surface water systems in the Upper Missouri and Ohio River Basins.

The National Geologic Mapping Program conducts prioritized investigations relevant to social and scientific issues facing the nation, such as the susceptibility of ground water to contamination from agricultural activities. Resulting map products and research include information about the distribution, composition, stratigraphic setting, and geologic history of Earth materials. The GEOINDEX data base contains references to modern geologic mapping. In addition, the PLUTO data base contains geochemical data on rocks, soils, sediments, plants, water, and other materials.

7.3.2 Fish and Wildlife Service (FWS)

The Fish and Wildlife Service is responsible for migratory birds, endangered species, certain marine mammals, inland sport fisheries, and specific fishery and wildlife research activities. In particular, FWS has the primary responsibility for enforcing the Endangered Species Act. Threatened or endangered species are an ecological concern in developing pesticide SMPs for critical habitat areas where ground water is closely hydrologically connected with surface waters. To address issues related to routine field applications of pesticides affecting terrestrial or surface water critical habitat areas, many States are working with the FWS and EPA's FIFRA program to add protection measures to species recovery plans for organisms ranging from the leopard darter to numerous migratory birds. Features of these species recovery plans might also apply to protection provisions in Pesticide SMPs.

7.3.3 Additional Sources from the U.S. Department of Interior

The Bureau of Land Management (BLM), the Office of Surface Mining Reclamation and Enforcement (OSM), and the Bureau of Reclamation may also provide ground water data, especially in western States with large tracts of public lands. The BLM is responsible for the total management of more than 270 million acres of public lands. In addition to managing watersheds to protect soil and enhance water quality, BLM manages wildlife habitat, endangered plant and animal species, and designated conservation and wilderness areas.

The primary goal of the Office of Surface Mining Reclamation and Enforcement is to assist States in operating a nationwide program that protects society and the environment from the adverse effects of coal mining, while ensuring that surface coal mining can be practiced without permanent damage to land and water resources.

The Bureau of Reclamation administers a reclamation program that provides the arid and semiarid lands of the 17 contiguous western States a secure, year-round water supply for irrigation. The Bureau's functions include groundwater management, water quality and environmental enhancement, and development of water conservation plans.

The Bureau of Indian Affairs assists Indian and Alaska Native people in managing their own affairs under the trust relationship to the federal government. In particular, the Bureau can serve as a liaison between the States and many sovereign American Indian groups.

7.4 Sources of Information from the U.S. Department of Agriculture (USDA)

Of the 36 operating entities within the USDA, ten share responsibilities for implementing the President's Water Quality Initiative for Agriculture. Of these entities, nine USDA agencies particularly relevant for Pesticide SMPs are discussed in the following subsections.

7.4.1 Agricultural Stabilization and Conservation Service (ASCS)

The ASCS plays a central role in transfer of payments for major USDA commodity support programs. Starting with the 1985 Food Security Act (1985 Farm Bill), cross-compliance provisions required recipients of ASCS assistance to prepare and implement conservation plans, whose water quality protection features have become steadily more important. Under the President's Water Quality Initiative and provisions added in the 1990 Farm Bill reauthorization (1990 Farm Bill), the ASCS will work with the SCS and other USDA agencies to promote cost-sharing for special integrated crop management practices designed to protect ground water from agricultural chemicals. The outcome of these projects may be useful to States in the development of SMPs. The ASCS's ongoing Agricultural Conservation Program (ACP) also provides cost-share assistance for implementing a variety of water-quality-oriented BMPs.

7.4.2 Agricultural Research Service (ARS)

The ARS administers fundamental and applied research that address a wide-range of agriculture-related issues, including the conservation of soil, water, and air and the processing, storage, and distribution of farm products. The ARS has developed a number of fate and transport models that focus on pesticides. For example, Chemical Runoff, and Erosion from Agricultural Management Systems (CREAMS) and Ground Water Loading Effects from Agricultural Management Systems (GLEAMS) evaluate the effects of agricultural management practices on the transport of pesticides in the root zone, and describe rainfall, infiltration, and runoff processes. Pesticide degradation, volatization and plant uptake are also included in these models.

7.4.3 Cooperative State Research Service (CSRS)

A major responsibility of the CSRS is to fund research through the State Agricultural Experiment Station (SAES) for the advancement of science and technology in support of agriculture. Other research programs conducted by CSRS, and funded by special grants, include a ground water research grants program; a supplemental and alternative crop program; a low-input agricultural program; and the National Research Initiative (NRI) competitive grant programs in natural resources, water quality, ecosystems, and wetlands.

The SAES is responsible for the National Agricultural Pesticide and Impact Assessment Program (NAPIAP), which is a source for pesticide-use data. Specifically, the NAPIAP provides grant monies to States for conducting pesticide use and benefit studies that are mutually beneficial to States and NAPIAP. In addition, the CSRS is responsible for developing a forum for coordination between the State Agricultural Experiment Stations, the USDA, and other federal agency scientists.

7.4.4 Extension Service (ES)

The ES is the educational bureau of the USDA and serves as the federal partner in the Cooperative Extension System. More specifically, the ES coordinates its activities with State land grant universities and local county extension offices to conduct research and to provide outreach and technical assistance programs. The CES is especially active in supporting improved training of pesticide applicators and promoting integrated pest management programs (or similar integrated crop management or integrated farm management programs) and low-input sustainable agriculture techniques that can significantly reduce the use of pesticides.

7.4.5 National Agricultural Library (NAL)

The NAL provides information services over a broad range of agricultural interests, including alternative farming systems, biotechnology, technology transfer, and water quality. NAL maintains the AGRICultural OnLine Access data base (AGRICOLA), which provides an online bibliography of agriculture-related literature. NAL also maintains the USDA/CRIS (Current Research Information System) data base, which provides online access to information on federal- and State-supported research in agriculture, environmental protection, forestry, and related fields. The AGRIS data base serves as a comprehensive inventory of world-wide agricultural literature and is also maintained at NAL. In addition, the Water Quality Information Center (WQIC), within NAL, serves as a focal point for disseminating information related to quality and quantity of water resources as they affect or are affected by agricultural production practices.

7.4.6 Forest Service (FS)

The FS is a national leader in forestry through its management of the National Forest System. A key objective of the FS is to promote natural resource conservation through cooperative efforts with other federal, State, and local agencies. The FS provides technical assistance to State forestry programs in order to protect and improve the quality of air, water, and soil resources. Also, the FS's National Forest Assistance provides information on the use of pesticides in modern silvicultural practices.

7.4.7 Soil Conservation Service (SCS)

The primary responsibility of the SCS is to develop and implement a National Soil and Water Conservation Program in cooperation with landowners and operators, resource groups, and other federal and State agencies. As part of this effort, the Soil Conservation Service provides technical assistance to other USDA entities and to State soil and water conservation districts for developing management practices. These management practices are frequently adopted by States as water quality best management practices. In preparing the standards and specifications for proper pesticide use practices, the SCS has developed a considerable amount of information on the suitability of common pesticides for specific soils, cropping systems, and locations within each State. This information can be beneficial in developing Pesticide SMPs. The SCS developed the Soil/Pesticide Interaction Screening Procedure (SPISP) to assist in screening soil-pesticide interactions. SPISP was designed to assist field personnel in determining if the use of a particular pesticide on a given soil may result in pesticide losses of sufficient size to be detrimental to a water resource of concern. The results are intended to be a first tier evaluation of pesticide use and was developed on the results of several thousand runs of the GLEAMS model.

7.4.8 Economic Research Service (ERS) and National Agricultural Statistics Service (NASS)

The ERS and the NASS work with State departments of agriculture to gather estimates on production characteristics for major farm commodities. Such statistics currently constitute one way to build county profiles of pesticide use based on indirect evaluation techniques. ERS and NASS are initiating a new program to begin actual data gathering on pesticide use. As this program expands, it should provide a more direct means of estimating agricultural pesticide use patterns within a State.

7.5 Sources of Information from the National Oceanic and Atmospheric Administration (NOAA)

NOAA's mission includes exploring, documenting, and predicting conditions in the atmosphere and ocean, and managing and disseminating long-term environmental information. NOAA also conducts extensive research related to the protection of marine resources and their habits. In addition, NOAA provides satellite observations of the environment by operating an environmental satellite system.

NOAA has begun a program to document major types of pollutant discharges to coastal waters. The National Coastal Pollutant Discharge Inventory (NCPDI) includes estimates on the use of such agrichemicals as fertilizers and pesticides in 78 estuarine drainage areas rimming the contiguous United States. NOAA has also developed a vulnerability index to facilitate relative comparisons of potential risks from pesticide usage.

This information can be helpful in building a pesticide use data base for coastal areas within a State.

The 1990 Amendments to the Coastal Zone Management Act (CZMA) of 1972 will require enhanced treatment of nonpoint source pollution in all State coastal management programs. Changes are also required in State Clean Water Act Section 319 Nonpoint Source (NPS) Plans as a result of the CZMA Amendments. A key provision of the CZMA amendments will lead to the development of federal guidance containing a detailed technical description of BMPs for improving water quality. This BMP technical guidance should include many protection or remediation practices that would be useful in pesticide SMPs. The Coastal Nonpoint Source Program (CNPS) is a development of State programs to ensure implementation of NPS management measures to restore and protect coastal waters.

7.6 Other Sources

There are a number of centers associated with nonprofit foundations or government trusts that could be valuable sources of information in developing pesticide SMPs. The following selection of organizations is hardly exhaustive but does give brief descriptions of several important organizations.

7.6.1 Institute for Alternative Agriculture

The Institute serves as a major national clearinghouse for information on cost-effective alternative farming practices, which reduce the potential for ground water contamination from pesticides.

7.6.2 Land Stewardship Project

The Project is an important center in the Midwest for addressing issues that relate to alternative technology, specifically low-input sustainable agriculture.

7.6.3 Conservation Technology Information Center

The Center is a clearinghouse for information encouraging conservation systems for soil, water, and croplands. The Center provides fact sheets on a variety of topics related to ground water protection from agricultural chemicals. The Center has been very active in efforts in the Midwest associated with Clean Water Act programs, including the Section 319 NPS Management Program and the Great Lakes Program.

7.6.4 National Fertilizer and Environmental Research Center (NFERC)

NFERC has long been a major regional clearinghouse for information on the proper use of fertilizer materials. Its mission was broadened in 1990 to encompass a wider set of environmental concerns. NFERC and the Tennessee Valley Authority have been very active in developing management strategies for nonpoint source pollution issues in the Appalachians.

7.6.5 National Pesticide Information Retrieval System (NPIRS)

NPIRS is a data base maintained by Purdue University containing EPA and State registration information on more than 60,000 federally registered pesticide products and other non-pesticide chemicals. Information available from the data base includes product-specific data, State product data, experimental use permits, and emergency exemptions. The facility also provides fact sheets on specific pesticide products with regional estimates of use patterns, scientific findings on the chemical, tolerance assessments, and problems known to occur with use of the chemical.

7.6.6 Fish and Wildlife Information Exchange (FWIE)

The national support center for the FWIE is attached to the Department of Fisheries and Wildlife at Virginia Polytechnic and State University. With assistance from the U.S. FWS and endorsements from a wide variety of natural resource agencies (including EPA) and conservation groups, FWIE can provide States with the information to establish a detailed data base system on the life histories and habitat requirements for most types of fish and wildlife. States can then customize their systems in a variety of ways. Over half the States are currently FWIE users. FWIE is building a consistent data base structure for applications related to threatened and to endangered species and other conservation biology projects.

7.6.7 National Center for Food and Agricultural Policy (NCFAP)

NCFAP has compiled a comprehensive data base of herbicide use in agricultural crop production throughout the United States. The data base links usage estimates to crop acreage estimates from the 1987 Census of Agriculture. Reports and data summaries for this data base can be acquired on national, State, and local levels. The reports contain background information, extensive tabular material, and source lists and feature a comprehensive set of herbicide use profiles specific to their particular areas of focus, ranging from a summary of herbicide-use data nationwide to county-specific uses of particular active ingredients.

7.7 Contacts

Table 7-2 provides contacts for obtaining information discussed in Sections 7.2 through 7.6. The information presented in Table 7-2 is organized in the order that the sources appeared in the chapter. For the National Agricultural Pesticide Impact Assessment Program (NAPIAP), a complete list of representatives is presented in Table 7-3. Table 7-4 provides contact information for National Agricultural Statistics Service (NASS) State Statisticians.

Table 7-2. Sources of Technical Information

AGENCY / SOURCE	PHONE NUMBER	CONTACT
Environmental Protection Agency		
National Survey of Pesticides	(703) 305-5805	Office of Pesticide Programs
Phase I Report	(703) 487-4600	National Technical Information Service
Phase II Report	(same as Phase I report)	(same as Phase I report)
Data Base	(919) 541-2385	EPA National Computer Center
Pesticides Information Network	(703) 305-7187	User Support Staff
Comprehensive Conservation and Management Plans	(202) 260-1952	Oceans and Coastal Protection Division
Nitrogen Action Plan	(202) 260-5484	Rob Wolcott
National Estuarine Program		
Chesapeake Bay Program	1-800-523-2281	Nonpoint Source/Pesticides Coordinator Lorrie Roeser or Toxics Coordinator Richard Batiuk
Clean Water Act		
State Assessment Reports and Management Plans	(202) 260-7040	Assessment and Watershed Protection Division
Nonpoint Source Program	(202) 260-7100	Assessment and Watershed Protection Division
Waterbody System	(202) 260-3667	Assessment and Watershed Protection Division
Section 304 Water Quality Criteria	(202) 260-5400	Office of Science and Technology
NPDES	(202) 260-7166	Office of Wetlands, Oceans, and Watersheds

Table 7-2. Sources of Technical Information (continued)

AGENCY / SOURCE	PHONE NUMBER	CONTACT
Safe Drinking Water Act		
Public Water Supply Program	(800) 426-4791	Safe Drinking Water Hotline
Wellhead Protection	(same as PWS Program)	(same as PWS Program)
Sole Source Aquifer	(same as PWS Program)	(same as PWS Program)
UIC Program: Class V Wells	(same as PWS Program)	(same as PWS Program)
Comprehensive State Ground Water Protection Program	(202) 260-7077	Ground Water Protection Office
FRDS	(800) 426-4791	Safe Drinking Water Hotline
STORET	(202) 260-7050	Office of Water Louis Hoelman
ORD Ground Water Research Program Operation of CEAM		
PRZM, DBAPE, etc.	(706) 546-3549	Model Distribution Coordinator Catherine Green
FATE	(706) 546-3198	Heinz Kollig
Subsurface Processes	(405) 332-2224	Clint Hall
Fate and Transport Models for Pesticides	(706) 546-3210	Bob Carsel
Ground Water Monitoring for Pesticides and Use of GIS for Pesticide Management	(702) 798-2598	Joe Dlugosz
Pollution Prevention Initiative	(202) 260-3557	David Kline
Ground Water Research Publications	(513) 569-7562	Center for Environmental Research Information
LISTS	(702) 798-2648	Head Librarian Rose Randazzo Ellis
AQUIRE	(218) 720-5564	Christine L. Russom
IRIS	(513) 569-7596	IRIS Manager Pat Daunt
TRIS	(202) 260-1531	Office of Pollution Prevention Lisa Capozzoli

Table 7-2. Sources of Technical Information (continued)

AGENCY / SOURCE	PHONE NUMBER	CONTACT
U.S. Department of Interior		
U.S. Geological Survey	(703) 648-4302	(general information)
NAWDEX	(703) 648-5684	Water Resources Division James Burton
WATSTORE	(same as NAWDEX)	(same as NAWDEX)
RASA	(703) 648-5035	Office of Ground Water William Alley, Chief of the Office of Ground Water
GEOINDEX	(703) 648-4380	Geologic Inquiries Group Virginia Major
PLUTO	(303) 236-1194	Geologic Division Art Sutton
Fish and Wildlife Service	(703) 358-2171	Division of Endangered Species Robert Ruesink
Species Recovery Plans		Dr. John Fay
Bureau of Land Management	(202) 208-4896	Deputy Assistant Director for Land and Renewable Resources Kemp Conn
Office of Surface Mining Reclamation and Enforcement	(202) 208-2719	Office of Public Affairs
Bureau of Reclamation	(202) 208-4442	Technical Liaison Division Judy Troast
Bureau of Indian Affairs	(202) 208-4791	Fred Hamann
U.S. Department of Agriculture	(202) 720-2791	(general information)
Agricultural Stabilization and Conservation Service	(202) 720-7333	Agricultural Conservation Program
Agricultural Research Service	(912) 386-7173	Soil Scientist, Ralph Leonard
(CREAMS and GLEAMS)	(912) 386-3889	Computer Programmer Frank Davis
Cooperative State Research Service	(202) 401-4555	Dr. Colien Hefferan, Acting
National Agricultural Pesticide Impact Assessment Program (NAPIAP)		Refer to NAPIAP State contact list (Table 4-3)
NAPIAP Special Projects	(202) 401-4866	Willis Wheeler
State Agricultural Experiment Stations	(202) 401-4555	Dr. Colien Hefferan, Acting

Table 7-2. Sources of Technical Information (continued)

AGENCY / SOURCE	PHONE NUMBER	CONTACT
Extension Service	(202) 720-3029	Janet Pauly or contact the Director of your State Cooperative Extension Service
National Agricultural Library		
AGRICOLA Data Base	(301) 504-5479	Reference desk
CRIS Data Base	(301) 504-5414	Information Services Branch Robyn C. Frank
AGRIS Data Base	(same as CRIS)	(same as CRIS)
Water Quality Information Center	(301) 504-6875	(general information)
Forest Service	(202) 205-1473	National Forest System Assistance, Watershed and Air Staff
Soil Conservation Service	(202) 205-0026 (202) 720-1546	Office of Public Affairs Judy Johnson or Contact State Conservationist
Economic Research Service	(202) 219-0433	Resource and Technology Division, Survey and Data Section Merritt Padgitt
National Agricultural Statistics Service	(202) 720-9579	Report Section, Dissemination Group George Patton or State Statistician
Farm-*A*-Syst	(608) 262-0024	Farm-*A*-Syst Office (general information)
NOAA		
National Coastal Pollutant Discharge Inventory (NCPDI)	(301) 713-3000	National Ocean Service, Office of Resource Conservation and Assessment Dan Farrow or Tony Pait
Vulnerability Index	(same as NCPDI)	(same as NCPDI)
CZMA/Water Quality BMPs	(202) 260-7110	EPA, Steve Dressing

Table 7-2. Sources of Technical Information (continued)

AGENCY / SOURCE	PHONE NUMBER	CONTACT
Other Sources		
Institute for Alternative Agriculture	(301) 441-8777	Neil Schaller
USDA/ Alternative Farming Systems Information Center	(301) 504-6559	Jane Gates
Land Stewardship Project	(612) 433-2770	Managing Director George Booty
Conservation Technology Information Center	(317) 494-9555	Water Quality Specialist Lynn Kirschner
National Fertilizer and Environmental Research Center	(205) 386-2026	Ronald Ritschard
National Pesticide Information Retrieval Systems	(317) 494-6614	User Services Specialist Virginia Walters
Fish and Wildlife Information Exchange	(703) 231-7348	Project Leader Jeff Waldon
National Center for Food and Agricultural Policy	(202) 328-5036	Leonard Gianessi

Table 7-3. National Agricultural Pesticide Impact Assessment Program List of State Liaison Representatives

STATE	CONTACT PERSON & ADDRESS	PHONE/FAX
Alabama	Dr. Harold Walker Department of Agronomy & Soil Auburn University Auburn, AL 36849	Tel: 205-844-3994 Fax: 205-844-3945
Alaska	Mr. Wayne Vandre Coordinator, Pesticide Programs Cooperative Extension Service 2221 E. Northern Lights Boulevard #118 University of Alaska Anchorage, AK 99508	Tel: 907-279-6575 Fax: 907-279-2139
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Arkansas	Dr. Robert Frans Altheimer Laboratory Department of Agronomy 276 Altheimer Drive University of Arkansas Fayetteville, AR 72703	Tel: 501-575-3978 Fax: 501-575-3975
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Table 7-3. National Agricultural Pesticide Impact Assessment Program List of State Liaison Representatives (continued)

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District of Columbia	Dr. Mohammed S. Khan University of the District of Columbia 901 Newton Street, N.E. Cooperative Ext. Service Washington, D.C. 20017	Tel: 202-576-7419 Fax: 202-576-8712
Florida	Dr. Norman Nesheim Pesticide Information Office Building 847 University of Florida Gainesville, FL 32611	Tel: 904-392-4721 Fax: 904-392-1988
Georgia	Dr. Keith Delaplane Department of Entomology 200 Barrow Hall University of Georgia Athens, GA 30602	Tel: 706-542-1765 Fax: 706-542-3872
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Table 7-3. National Agricultural Pesticide Impact Assessment Program List of State Liaison Representatives (continued)

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Maine	Dr. James Dill UMCE-Pest Management Office 491 College Avenue Orono, ME 04473	Tel: 207-581-3879 Fax: 207-581-3881
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Table 7-3. National Agricultural Pesticide Impact Assessment Program List of State Liaison Representatives (continued)

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Table 7-3. National Agricultural Pesticide Impact Assessment Program List of State Liaison Representatives (continued)

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Table 7-3. National Agricultural Pesticide Impact Assessment Program List of State Liaison Representatives (continued)

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Table 7-3. National Agricultural Pesticide Impact Assessment Program List of State Liaison Representatives (continued)

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Table 7-3. National Agricultural Pesticide Impact Assessment Program List of State Liaison Representatives (continued)

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Table 7-4. Contact Information for National Agricultural Statistics Services (NASS) State Statisticians

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Alaska	Palmer	(907) 745-4272
Arizona	Phoenix	(602) 280-8850
Arkansas	Little Rock	(501) 324-5145
California	Sacramento	(916) 551-1533
Colorado	Lakewood	(303) 236-2300
Delaware	Dover	(302) 739-4811
Florida	Orlando	(407) 648-6013
Georgia	Athens	(706) 546-2236
Hawaii	Honolulu	(808) 973-9588
Idaho	Boise	(208) 334-1507
Illinois	Springfield	(217) 492-4295
Indiana	West Lafayette	(317) 494-8371
Iowa	Des Moines	(515) 284-4340
Kansas	Topeka	(913) 233-2230
Kentucky	Louisville	(502) 582-5293
Louisiana	Baton Rouge	(504) 922-1362
Maryland	Annapolis	(410) 841-5740
Michigan	Lansing	(517) 377-1831
Minnesota	St. Paul	(612) 290-2230
Mississippi	Jackson	(601) 965-4575
Missouri	Columbia	(314) 876-0950
Montana	Helena	(406) 449-5303
Nebraska	Lincoln	(402) 437-5541
Nevada	Reno	(702) 784-5584
New England	Concord, New Hampshire	(603) 224-9639
New Jersey	Trenton	(609) 292-6385

Table 7-4. Contact Information for National Agricultural Statistics Services (NASS) State Statisticians (continued)

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New Mexico	Las Cruces	(505) 522-6023
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North Carolina	Raleigh	(919) 856-4394
North Dakota	Fargo	(701) 239-5306
Ohio	Columbus	(614) 469-5590
Oklahoma	Oklahoma City	(405) 525-9226
Oregon	Portland	(503) 326-2131
Pennsylvania	Harrisburg	(717) 787-3904
South Carolina	Columbia	(803) 765-5333
South Dakota	Sioux Falls	(605) 330-4235
Tennessee	Nashville	(615) 781-5300
Texas	Austin	(512) 482-5581
Utah	Salt Lake City	(801) 524-5003
Virginia	Richmond	(804) 786-3500
Washington	Olympia	(206) 902-1940
West Virginia	Charleston	(304) 558-2217
Wisconsin	Madison	(608) 264-5317
Wyoming	Cheyenne	(307) 772-2181

7.8 References

Congress of the United States, OTA. 1990. Beneath the Bottom Line: Agricultural Approaches to Reduce Agrichemical Contamination of Groundwater. Circular 900. OTA-F-418. NTIS PB91-129874. 34 pp.

Daniel III, C.C. 1990. Evaluation of Site-Selection Criteria, Well Design, Monitoring Techniques, and Cost Analysis for a Ground Water Supply in Piedmont Crystalline Rocks. USGS Water-Supply Paper 2341-B. NTIS PB91-154641.

Dumochelle, D.H., E.A. Lynch, and T.R. Cummings. 1990. A Literature Survey of Information on Well Installation and Sample Collection Procedures Used in Investigations of Ground Water Contamination by Organic Compounds. USGS Open-File Report 90-378.

Fedkiw, John. 1991. Nitrate Occurrence in U.S. Waters (and Related Questions). A reference summary of published sources from an agricultural perspective. National Agricultural Library. Call ATD427 N5F43. NTIS PB92-155696/GAR.

Frimpter, M.H., J.J. Donohue, IV, and M.V. Rapacz. 1990. A Mass-Balance Nitrate Model for Predicting the Effects of Land Use and Ground Water Quality. USGS Open-File Report 88-493.

Gibs, Jacob, T.E. Imbrigiotta, and Kenneth Turner. 1990. Bibliography on Sampling Ground Water for Organic Compounds. USGS Open-File Report 90-564.

Hardy, M.A., P.P. Leahy, and W.M. Alley. 1989. Well Installation and Documentation, and Ground Water Sampling Protocols for the Pilot National Water Quality Assessment Program. USGS Open-File Report 89-396,

Heath, R.C. 1989. Basic Ground Water Hydrology. USGS Water-Supply Paper 2220.

Jorgensen, D.G. 1989. Using Geophysical Logs to Estimate Porosity, Water Resistivity, and Intrinsic Permeability. USGS Water-Supply Paper 2321.

Lapham, W.W. 1989. Use of Temperature Profiles Beneath Streams to Determine Rates of Vertical Ground Water Flow and Vertical Hydraulic Conductivity. USGS Water-Supply Paper 2337. NTIS PB179938.

Lohman, S.W. 1989. Ground Water Hydraulics. USGS Professional Paper 708.

National Agricultural Statistics Service and Economic Research Service. Agricultural Chemical Usage: 1990 Field Crops Summary. 1991. ERS/NASS; telephone: 800-999-6779.

USDA Soil Conservation Service. 1991. Screening Procedure for Soils and Pesticides Relative to Potential Water Quality Impacts. SCS; telephone: 817-334-5422.

USDA Extension Service, Water Quality Initiative Team. July 1990. Bibliography: Cooperative Extension System's Water Quality Education Materials.

USDA Extension Service, Water Quality Initiative Team. July 1990. Summary: Cooperative Extension System's 1990 State Water Quality Projects.

USDA National Agricultural Library. January 1982-July 1990. Managing Nonpoint Sources of Pollution. Quick Bibliography Series. QB-91-50.

USDA National Agricultural Library. January 1982-July 1990. Monitoring Water for Agricultural Wastes and Agrichemicals. Quick Bibliographic Series. QB 91-52.

USDA National Agricultural Library. January 1982-July 1990. Regulating Water Quality: Policy, Standards and Laws. Quick Bibliographic Series. QB 91-49.

USDA National Agricultural Library. January 1985-July 1990. Allocation of Water Resources. Quick Bibliography Series. QB-91-51.

USDA National Agricultural Library. January 1990-July 1991. Water Quality Implications of Conservation Tillage. Quick Bibliography Series. Beltsville, MD. QB 91-145.

U.S. EPA, Office of Ground Water and Drinking Water. 1991. Wellhead Protection Strategies for Confined Aquifer Settings. EPA 570/9-91-008.

U.S. EPA, Office of Ground Water and Drinking Water. 1991. Delineation of Wellhead Protection Areas in Fractured Rocks. EPA 570/9-91-008.

U.S. EPA, Office of Ground Water and Drinking Water. 1991. Protecting Local Ground Water Supplies Through Wellhead Protection. EPA 570/9-91-007.

U.S. EPA, Office of Ground Water and Drinking Water. May 1992. Definitions for the Minimum Set of Data Elements for Ground Water Quality.

U.S. EPA, Office of Pesticide Programs. 1992. Integrating EPA's Agriculture and Water Grant Programs.

U.S. EPA, Office of Ground Water Protection. 1985. Ground Water Monitoring Strategy. NTIS PB-111886/AS. EPA 440/6-85-008.

U.S. EPA, Office of Ground Water Protection. 1987. An Annotated Bibliography of Wellhead Protection References. NTIS PB88-148754/AS. EPA 440/6-87-014.

U.S. EPA, Office of Ground Water Protection. 1987. Ground Water Data Requirements Analysis. NTIS PB87-22532-AS. EPA 440/6-87-005.

U.S. EPA, Office of Ground Water Protection. 1987. Guidelines for Delineating Wellhead Protection Areas. NTIS PB88-111430-AS. EPA 440/6-87-010.

U.S. EPA, Office of Ground Water Protection. 1987. Surface Geophysical Techniques for Aquifer and Wellhead Protection Area Delineation. NTIS PB88-229505/AS. EPA 440/6-87-016.

U.S. EPA, Office of Ground Water Protection. 1988. Developing a State Wellhead Protection Program: A User's Guide to Assist State Agencies Under the Safe Drinking Water Act. NTIS PB89-173751/AS. EPA 440/6-88-003.

U.S. EPA, Office of Ground Water Protection. 1988. Model Assessment for Delineating Wellhead Protection Areas. NTIS PB88-231485/AS. EPA 440/6-88-002.

U.S. EPA, Office of Ground Water Protection. 1988. Protecting Ground Water: Pesticides and Agricultural Practices. NTIS PB88-230628/AS. EPA 440/6-88-001.

U.S. EPA, Office of Ground Water Protection. 1989. Indicators for Measuring Progress in Ground Water Protection. EPA 440-6-88-006.

U.S. EPA, Office of Ground Water Protection. 1989. Wellhead Protection Program: Tools for Local Governments. EPA 440/6-89-02.

U.S. EPA, Office of Ground Water Protection. 1990. Compendium of Federal Financial Assistance Programs. Targeting Programs for State and Local Ground Water Protection. EPA 440/6-90-008.

U.S. EPA, Office of Ground Water Protection. 1990. Hydrogeologic Mapping Needs for Ground Water Protection and Management: Workshop Report. EPA 440/6-90-002.

U.S. EPA, Office of Water. Undated. Office of Water Environmental and Program Information Systems Compendium: Fiscal 1990. EPA 500/9-90-002.

U.S. EPA, Office of Water, Office of Ground Water Protection. 1988. Protecting Ground Water: Pesticides and Agricultural Practices. EPA 440/6-88-001.

U.S. EPA, Office of Water, Office of Pesticides and Toxic Substances. 1990. National Survey of Pesticides in Drinking Water Wells: Phase I Report. NTIS PB91-125765. EPA 570/9-90-015.

U.S. EPA, Office of Water, Office of Pesticides and Toxic Substance. January 1992. Another Look: National Survey of Pesticides in Drinking Water Wells: Phase II Report. EPA 579/09-91-020.

U.S. EPA, Office of Research and Development, Environmental Research Laboratory. October 1991. FATE: The Environmental Fate Constants Information System Data Base. User's Manual. Version I-A. Center for Exposure Assessment Modeling, Athens, Georgia; telephone: (404) 546-3770.

Utah State University and Cooperative Extension Service. Undated. Pesticide Data on Potential Impacts to Ground Water and Surface Water.

GLOSSARY

Abiotic Degradation: Chemical decomposition brought about by physical or chemical processes.

Absorption: The passage of one substance into or through another; e.g., an operation in which one or more soluble components of a gas mixture are dissolved in a liquid.

ACP: Agriculture Conservation Program.

Action Levels: Reference points for response to (pesticide) contamination of ground water, set at fractions of MCLs.

Adsorption: The adhesion in an extremely thin layer of molecules (as of gases, solutes, or liquids) to the surfaces of solid bodies or liquids with which they are in contact.

AGRICOLA: AGRICultural OnLine Access data base.

Agricultural DRASTIC: This method uses a relative ranking system for seven soil/aquifer parameters to form, via an additive model, a continuous numerical index. The index is intended to represent the area's relative degree of pollution potential by pesticides.

Agronomic: A branch of agriculture dealing with field crop production and soil management.

Ambient Monitoring: Monitoring to determine the background quality of groundwater.

Analytes: Chemicals tested for in an analysis.

Analytical Contaminant Transport Models: This type of model combines a two-dimensional analytical model, to compute the time-varying distribution and dissipation of the pesticide DBCP in the plow layer, with a one-dimensional numerical model to simulate both water and DBCP movement in a layer profile.

Aquifer: A subsurface, saturated geologic formation or group of formations capable of economically yielding usable amounts of ground water from wells and springs.

Aquifer Recharge Areas: That portion of the drainage basin in which the net saturated flow of ground water is directed away from the water table.

Aquifer Sensitivity: The intrinsic susceptibility of an aquifer to pesticide contamination. Sensitivity is related solely to the hydrogeologic characteristics of the aquifer and the overlying geologic materials. Sensitivities unrelated to agricultural practices, the degree of pesticide toxicity, and the nature of exposure, if any, to human or other populations.

Aquifer Vulnerability: Susceptibility of an aquifer to contamination resulting from the combined effects of intrinsic sensitivity of the aquifer and the agricultural practices used.

AQUIRE: Aquatic Toxicity Information Retrieval Data Base.

ASCS: Agricultural Stabilization and Conservation and Conservation Service.

Base Flexibility: Allows farmers who participate in the Federal commodity support programs to rotate crops and plant a greater variety of crops on acres that were previously tied to specific crop.

Baseline Monitoring: Measurement of ground water quality, used to establish quality of the ground water in a given aquifer prior to the onset of activities that may alter the water quality.

Biodegradation: Chemical degradation brought about by living organisms.

Biological Pest Control: Agricultural techniques used to enhance natural mechanisms that can control pests at economically tolerable threshold levels. Techniques include use of antagonists, predators, self-defense mechanisms, parasites, and insect pathogens.

Biotic: Pertaining to life or specific life conditions.

BMP: Best Management Practices are methods or measures designed to prevent or reduce ground water contamination from pesticides.

BPJ: Best Professional Judgment.

California's Hot Spot: This ground water vulnerability assessment method utilizes information on sensitive areas including depth to ground water, soil texture, and annual precipitation or irrigation. The overlay maps for each available factor are stacked to determine sensitive areas. After preliminary screening of sensitive areas, quantitative field investigations are taken to further define and verify sensitive areas.

Carcinogen: Any substance that can cause or contribute to the production of cancer.

C&T: Certification and Training programs for pesticide applicators.

Catalyst: A substance that initiates a chemical reaction and enables it to proceed under different conditions than otherwise possible.

CEAM: Center for Exposure Assessment Modeling.

CES: Cooperative Extension Service.

CFR: Code of Federal Regulations.

CLP: Superfund's Contract Laboratory Program.

Chemigation: The practice of mixing pesticides or fertilizers with irrigation water and applying the mixture to cropped fields.

CMIS: Chemical Movement in Soil considers a 60-cm root zone and calculates the amount of pesticide leaching past that depth for any given time.

Chronic Toxicity: The capacity of a substance to cause long-term poisonous human health effects.

Contaminant: Any physical, chemical, biological, or radiological substance or matter that has an adverse effect on air, water, or soil.

Contour Plowing: Practice of plowing along the contour of the land in order to inhibit erosion. The practice also inhibits travel of pesticides to surface waters.

CREAMS; GLEAMS: These models evaluate the effects of agricultural management practices on transport of pesticides in the root zone, and describe rainfall, infiltration, and runoff process. Pesticide degradation, volatilization, and plant uptake are also included in the models.

Crop Rotation: The successive planting of different crops in the same field over a period of years. Increases the health of crops by controlling multi-year buildup of crop-specific pests, thus decreasing the need to use pesticides.

Cross-Compliance Measures: Semivoluntary measures associated with compliance incentives.

CZMA: Coastal Zone Management Act of 1972, enforced through the National Oceanic and Atmospheric Agency.

DBAPE: Data Base Analyzer Parameter Estimator.

Degradation: The breakdown of a pesticide into reaction products, generally of less complex form.

Degradation Rate: The rate of which a pesticide is broken down to a less complex form.

Detection: The discovery of the presence of a ground water constituent during monitoring for indicator parameters, specific pesticides, or pesticide reaction products.

Detection Limits: Concentration values below which the instrument is unable to measure presence of the analyte.

Discriminant Statistical Analysis/Soil Taxonomy and Surveys: This method uses a multivariation statistical approach (Fisher's Linear Discriminant analysis) with soil taxon units to delineate sensitive areas. The method utilizes soil survey reports, the U.S. rectangular coordinate system, and available ground water pesticide analyses data.

Ecosystem: The interacting system of a biological community and its non-living environmental surroundings.

EPA: U.S. Environmental Protection Agency.

Epidemiologic: The sum of factors controlling the presence or absence of a disease or pathogen.

ERS: The Economic Research Service of the U.S. Department of Agriculture.

Estuarine: Pertaining to a water passage where the tide meets a river current.

ETU: Ethylene Thiourea. A pesticide metabolite.

Evaluation/Effectiveness Monitoring: Observation and testing of ground water quality to determine the effectiveness of an SMP in preventing ground water contamination.

Evapotranspiration: The sum of evaporation plus transpiration.

FDA: Federal Drug Administration.

FIFRA: Federal Insecticide, Fungicide, and Rodenticide Act.

Filter Pack: Clean uniform sand or gravel that is placed in a well between the borehole wall and the well screen to prevent formation material from entering the screen.

Foliar application: The treatment of plant surfaces with pesticides.

FRDS: Federal Reporting Data system.

Fungicide — (chemical): Agent that destroys fungi or inhibits their growth.

FWS: Fish and Wildlife Service.

GC/MS: Gas chromatography/Mass Spectroscopy.

Geology: A science that deals with the history of the earth and its life, especially as recorded in rocks.

Geomorphic: Of or relating to the form of the earth or a celestial body (as the moon) or its solid surface features.

GIS: Geographic Information System.

GLPs: Good Laboratory Practices. Standards for testing conducted in the fie field and for such disciplines of testing as ecological effects, chemical level, and residue chemistry. These standards are regulated under FIFRA.

Ground Water: The supply of fresh water found beneath the Earth's surface, usually in aquifers, which is often used for supplying wells and springs. Because ground water is a major source of drinking water there is growing concern over areas where leaching agricultural or industrial pollutants or substances from leaking under ground storage tanks are contaminating ground water.

GSMP: Generic State Management Plan.

GUS: Ground Water Ubiquity Score. This method calculates an index which is a numerical scale dividing pesticides into non-leachers, transitionals, and leachers. The GUS index is based on curve fittings between pesticide half lives and soil organic-carbon partitioning coefficients of three groups of pesticides.

HA: Health Advisory *(see HAL)*.

Headspace: The empty volume above the liquid in a container.

Health Advisory Level (HAL): The levels of chemical concentration in water that are acceptable for drinking.

Herbicide: An agent used to destroy or inhibit plant growth.

Hydraulic Conductivity: The rate of flow of water in gallons per day through a cross section of one square foot under a unit hydraulic gradient, at the prevailing temperature (gpd/ft^2). In the SI System, the units are $m^3/day/m^2$ or m/day.

Hydraulic Gradient: The rate of change in energy contained in a water mass that is produced by elevation, pressure or velocity, or per unit of distance of flow in a given direction.

Hydrogeologic: Refers to the interrelationships of geologic materials and processes with water, especially ground water.

Hydrolysis: A chemical process of decomposition involving splitting a bond and adding the elements of water.

Immunoassay: An assay procedure that utilizes a limited number of binding sites on an antibody to measure the amount of antigen (analyte) in the sample.

Integrated Pest Management (IPM): A pest population management system that anticipates and prevents pests from reaching damaging levels by using techniques such as natural enemies, pest-resistant plants, cultural management, and judicious use of pesticides. A mixture of pesticide and non-pesticide methods to control pests. IPM reduces total pesticide use while economically controlling pest-reduction efforts and maintaining the economic yield of the protected crop(s).

IPM/ICM: Integrated Pest and Crop Management.

IRIS: Integrated Risk Information System.

Irrigation: Technique for applying water or wastewater to land areas to supply the water and nutrient needs of plants.

Karst Topography: Refers to areas of sink holes, caves, and streamless valleys. A type of geographic terrain underlain by carbonate rocks where significant solution of the rock has occurred due to flowing ground water.

Leachability: The ability of a pesticide to percolate downward from the top soil layer.

Leachability Classes of Kansas Soils: This method was used to group Kansas soils into four classes of susceptibility based on the soil profile and water infiltration rate (permeability).

Leaching: The process by which soluble constituents are dissolved and carried down through the soil by a percolating fluid.

LEACHMP: A finite-difference model for simulating the fate of pesticides in the unsaturated zone during a single growing season. The model simulates the effects of layered soils, precipitation/evaportranspiration cycles, plant growth, and the transport of multiple metabolites as well as parent pesticides.

Lithology: The macroscopic character of a rock formation.

LUD: Limited Use Designation.

MCL: Maximum Contaminant Level.

MCLGs: Maximum Contaminate Level Goals.

MDLs: Method Detection Levels.

MECP: Michigan Energy Conservation Program.

Metabolite: A substance derived from the breakdown of a pesticide by microorganisms.

Microbe: A microorganism, bacteria, or fungus.

Monitoring: Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, animals, and other living things.

MOUSE: A set of mathematical models for tracing the transport and fate of pesticides in the unsaturated and saturated zones. It is used as a preliminary management tool in different soil-climate management regimes. MOUSE has four submodels: (1) Climatic data generator; (2) vadose zone at balance; (3) vadose zone solute transporter; and (4) aquifer water and solute transporter.

MSFWIS: Multi-State Fish and Wildlife Information Systems.

Multimedia: Affecting more than one environmental medium (e.g., ground water, surface water, soil, or air).

Multiple Regression Statistical Analyses: This multiple regression method was used to describe results of existing ground water contamination and factors affecting that contamination with six study areas in Nebraska. The researchers focused on nine independent variables including: hydraulic gradient; hydraulic conductivity; specific discharge; depth to water; well depth; annual precipitation; soil permeability; irrigation-well density, and annual nitrogen fertilizer use.

MWRA: Massachusetts Water Resources Authority.

NAL: National Agricultural Library.

NAPIAP: National Agricultural Pesticide Impact Assessment Program.

NASS: National Agricultural Statistics Service.

NAWDEX: National Water Data Exchange.

NCPDI: National Coastal Pollutant Discharge Inventory.

NEP: National Estuarine Program.

NFEDC: National Fertilizer and Environmental Development Center.

NFERC: National Fertilizer and Environmental Research Center.

Nitrate: A compound containing nitrogen which can exist in the atmosphere or as a dissolved gas in water and which can have harmful effects on humans and animals. Nitrates in water can cause severe illness in infants and cows.

NOAA: National Oceanic and Atmospheric Administration.

Nonpoint Source Pollution: Contamination (of groundwater) originating from a wide area, not from well-defined locations, a mobile or dispersed source of pollutants. Examples: acid rain deposition and contamination of surface water by salting roads; automobiles.

NPIRS: National Pesticide Information Retrieval System.

NPS Programs: Nonpoint Source Programs.

Nutrients: Organic and inorganic materials in soil that provide nourishment to plants.

OGWDW: EPA's Office of Ground Water and Drinking Water.

ORD: EPA's Office of Research and Development.

OPP: EPA's Office of Pesticide Programs.

Permeability: Water infiltration rate. (The rate at which liquids pass through soil or other materials in a specified direction.)

PESTANS I: One-dimensional, steady-State model that is limited to projecting vertical movement through the unsaturated zone.

PESTANS II: A two-dimensional numerical model that simulates both horizontal and vertical movement through the unsaturated zone.

Pesticide: Substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest. Also, any substance or mixture of substances intended for use as a plant regulator, defoliant, or desiccant.

Pesticide Fate: The end point of a pesticide or other contaminant after all processes have influenced it, including transport and degradation.

Pesticide Half-Life: The amount of time it takes for one-half of an amount of a pesticide to degrade.

Pesticide Transport: Movement of a pesticide through the environment, and the means by which it moves.

pH: Measure of the acidity or alkalinity of a solution.

Phreatic: In the zone of saturation.

Piezometer: Basic field device for measurement of hydraulic head (energy contained in a water mass, produced by elevation, pressure, or velocity), a tube or pipe in which the elevation of a water level can be determined. Piezometers are usually installed in groups so that they can be used to determine the direction of ground water flow.

PMZs: Pesticide Management Zones (California).

Polarity: Attraction toward a particular object or in a specific direction. The quality or condition inherent in a body that exhibits opposite properties or powers in opposite parts of directions or that exhibits contrasted properties or powers in contrasted parts or direction.

ppb: Parts per billion.

PQLs: Practical Quantitation Limits.

Prevention: Measures taken to control application or release of chemicals so as to minimize the chance of potential harmful effects to humans or the environment through contamination of a resource, such as ground water or surface water.

PRZM: A one-dimensional, finite-difference, pesticide transport model based on a pesticide mass-balance equation to evaluate leaching from the root zone under field crops. PRZM requires inputs of hydrology, crop, pesticide and oil information as well as daily meteorological data.

PSMP: Pesticide State Management Plan.

QAO: Quality Assurance Officer.

QAPPs: Quality Assurance Program Plans and/or Quality Assurance Project Plans.

QA/QC: Quality Assurance/Quality Control. QA functions are management tools that are independent of technical organization. QC functions are the integral activities within technical support projects that are designed to assure or control data precision and accuracy.

Quantification Limit: Level at which a concentration can be measured.

RASA: Regional Aquifer Systems Analysis Program.

Remediation: The process of reducing the harmful effects of contamination incidents.

Residue: Amount of a pollutant remaining in the environment after a natural or technological process has taken place, e.g., the sludge remaining after initial wastewater treatment, or particulate remaining in air after the air passes through a scrubbing or process.

Response: Actions initiated after a pesticide is detected in ground water.

Rodenticide: An agent (chemical) that kills, repels, or controls rodents.

Run-off: That part of precipitation, snow melt, or irrigation water that runs off the land into streams or other surface-water. It can carry pollutants from the air and land into the receiving waters.

RUSTIC: A union of the PRZM, VADOFT, and SAFTMOD models.

SAFTMOD: Two-dimensional, finite-element, flow and transport model for saturated flow below the water table.

Saturated Zone: The underground area in which water fills all of the available spaces.

Scouting: The inspection of a field for pests.

SCS: Soil Conservation Service.

SCWA: Suffolk County Water Authority, in New York.

SDWA: Safe Drinking Water Act.

Seep: A spot where a fluid (as water, oil, or gas) contained in the ground oozes slowly to the surface and often forms a pool.

SEEPAGE: This method uses a relative ranking system, for seven soil/aquifer paraments. Continuous numerical indexes called Site Index Numbers (SINs) are calculated for different areas and compared to determine the degree of aquifer sensitivity.

Silviculture: Tree farming.

Sinkhole: A natural depression on the land surface, generally occurring in limestone regions and formed by solution of rock or collapse of a cavern roof.

Siting Controls: Regulations on the location of potential sources of (ground water) contamination.

SMP: State Management Plans.

Soil Organic-Carbon Partitioning Coefficients: Soil adsorption coefficient normalized for the soil organic carbon content.

Soil Profile: A vertical section of the soil through all its horizons and extending into the parent material.

Soil Structure: The combination or arrangement of primary soil particles into secondary particles, units, or peds.

Soil texture: The relative proportion of the various soil separates in a soil (saw, silt, and clay).

SOP: Standard Operating Procedures.

Sorption: To take up and held by either adsorption or absorption.

SPISP: Soil-Pesticide Interaction Screening Procedure. This method determines the relative potential loss of a specific pesticide by surface runoff or by leaching below the root zone. Rates both soil potential and pesticide potential to leach. Ratings are used in leaching matrix format where potential 1 has a high probability of being lost via leaching; potential 2 has the possibility of being lost via leaching (but not as great as potential 1) and potential 3 has very low probability of being lost by leaching.

Spring: A source of water issuing from the ground.

States' Comprehensive State Ground Water Protection Philosophy: The ground water protection philosophy defines the waters to be considered in prevention, monitoring, and response plans.

STORET: Storage and retrieval of U.S. Waterways Parametric Data System.

Stratification: To divide into a series of graded strata.

Stratigraphic Setting: Layering of soils and rocks in a particular area.

Strip-Cropping: Growing crops in a systematic arrangement of strips or bands which serve as barriers to wind and water erosion.

TAD: Technical Assistance Document.

Topography: The physical features of a surface area including relative elevations and the position of natural and man-made features.

Toxic: Harmful to living organisms.

TRIS: Toxic Chemical Release Inventory System.

TVA: Tennessee Valley Authority.

TWC: Texas Water Commission.

Unsaturated Zone: The underground area below the soil layers but above the vadose zone and the water table in which water does not fill the available spaces.

Uptake: An act or instance of absorbing and incorporating especially into a living organism.

USDA: United States Department of Agriculture.

USGS: U.S. Geological Survey.

VADOFT: One-dimensional, finite-element, flow and transport model which simulates the flow from the bottom of the root zone to the top of the water table.

Vadose Zone: The underground zone containing water above the zone of saturation.

VIP: Uses numerical solution algorithms and nonequilibrium kinetics to describe the behavior of pesticides in the unsaturated zone and predict mass transport o the atmosphere and ground water.

VISA: Very Intensely Studied Area (Florida).

Volatility: Description of any substance that evaporates readily.

Washington's Map Overlays: This method determined sensitive areas by preparation of overlay maps for three hydrogeologic factors (presence of shallow water-table aquifers, high soil permeability, and intense irrigation). Visual inspection was used to quickly determine the sensitive areas and non-sensitive areas. The sensitive areas were then traced on 1:500,000 scale maps.

Watershed: A region or area bounded peripherally by a water parting and draining ultimately to a particular watercourse or body of water.

Water table: The level of ground water.

WATSTORE: National Water Storage and Retrieval System.

Well: A bored, drilled, or driven shaft, or a dug hole, whose depth is greater than the largest surface dimension and whose purpose is to reach underground water supplies or oil, or to store or bury fluids below ground.

Well Casing: A solid piece of pipe, typically steel or PVC plastic, used to keep a well open in either unconsolidated materials or unstable rock.

Well Seal: Low-permeability material that is emplaced to fill the annular space around a well.

Wellhead: The land-surface and subsurface area surrounding a water-supply well.

WHPAs: Wellhead Protection Areas.

Wisconsin's Ground Water Susceptibility Project: This method uses five hydrogeologic factors to determine ease of contaminant migration trough overlying materials to the ground water. These factors are depth to bedrock, type of bedrock, soil characteristics, depth to water table, and characteristics of surficial deposits. Each of the five factors' maps is put into digital form and overlaid to produce a composite map.

WSTB: Water Science and Technology Board.