United States
Environmental Protection
Agency

Robert S. Kerr Environmental
Research Laboratory
Ada OK 74820

Research and Development

EPA/600/S2-87/035 Sept. 1987

EPA

Project Summary

DRASTIC: A Standardized System for Evaluating Ground Water Pollution Potential Using Hydrogeologic Settings

Linda Aller, Truman Bennett, Jay H. Lehr, Rebecca Petty, and Glen Hackett

A methodology is described that will allow the pollution potential of any hydrogeologic setting to be systematically evaluated anywhere in the United States. The system has two major portions: the designation of mappable units, termed hydrogeologic settings, and the superposition of a relative rating system called DRASTIC.

Hydrogeologic settings form the basis of the system and incorporate the major hydrogeologic factors which affect and control ground-water movement including depth to water, net recharge, aquifer media, soil media, topography, impact of the vadose zone media and hydraulic conductivity of the aquifer. These factors, which form the acronym DRASTIC, are incorporated into a relative ranking scheme that uses a combination of weights and ratings to produce a numerical value called the DRASTIC Index.

Hydrogeologic settings are combined with DRASTIC Indexes to create units which can be graphically displayed on a map. The application of the system to 10 hydrogeologically variable counties resulted in maps with symbols and colors which illustrate areas of ground-water contamination vulnerability. The system optimizes the use of existing data to rank areas with respect to pollution potential to help direct investigations and resource expenditures and to prioritize protection, monitoring and clean-up efforts.

The full report was submitted in partial fulfillment of Contract No. CR-810715-01 by the National Water Well Association under sponsorship of the U.S. Environmental Protection Agency. This report covers a period from October 1983 to March 1987, and work was completed as of April 1987.

This Project Summary was developed by EPA's Robert S. Kerr Environmental Research Laboratory, Ada, OK, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

This research project was designed to create a methodology that will permit the ground-water pollution potential of any hydrogeologic setting to be systematically evaluated anywhere in the United States. The methodology has been incorporated into a standardized system that can be readily displayed on maps using existing information. The concepts inherent to the system were developed assuming a contaminant with the mobility of water, introduced at the surface and flushed into the ground water by precipitation. The methodology is designed to evaluate ground-water pollution potential from a regional perspective and should be applied to areas 100 acres or larger in size.

Results

The system that has been developed has two major parts, the designation of mappable units, termed hydrogeologic settings; and the superposition of a relative ranking system, called DRASTIC, which helps the user evaluate the relative ground-water pollution potential of any hydrogeologic setting.

The standardization system for evaluating ground-water pollution potential has been developed within the framework of an existing classification system of ground-water regions of the United States (Figure 1). These regions include:

1. Western Mountain Ranges
2. Alluvial Basins
3. Columbia Lava Plateau
4. Colorado Plateau and Wyoming Basin
5. High Plains
6. Nonglaciated Central Region
7. Glaciated Central Region
8. Piedmont and Blue Ridge
9. Northeast and Superior Uplands
10. Atlantic and Gulf Coastal Plain
11. Southeast Coastal Plain
12. Alluvial Valleys
13. Hawaiian Islands
14. Alaska
15. Puerto Rico and Virgin Islands

For the purpose of the present system Region 12 (Alluvial Valleys) has been incorporated into each of the other regions and Region 15 (Puerto Rico and Virgin Islands) has been omitted.

Because pollution potential cannot be determined on a regional scale smaller "hydrogeologic settings" were developed within each region. A hydrogeologic setting is a composite description of all the major geologic and hydrologic factors which affect and control ground-water movement into, through and out of an area. It is defined as a mappabl unit with common hydrogeologic cha acteristics, and as a consequenc common vulnerability to contaminatio These hydrogeologic settings form th basis of the system and permit furth delineation of the factors that affe pollution potential (Figure 2).

Inherent in each hydrogeologic settin are the physical characteristics th affect the pollution potential of groun water. After evaluating a number factors, the most important mappab factors that control ground-water poll tion potential were determined to be:

D—Depth to Water Table
R—(Net) Recharge
A—Aquifer Media
S—Soil Media
T—Topography (Slope)
I—Impact of Vadose Zone
C—Conductivity (Hydraulic) of th Aquifer

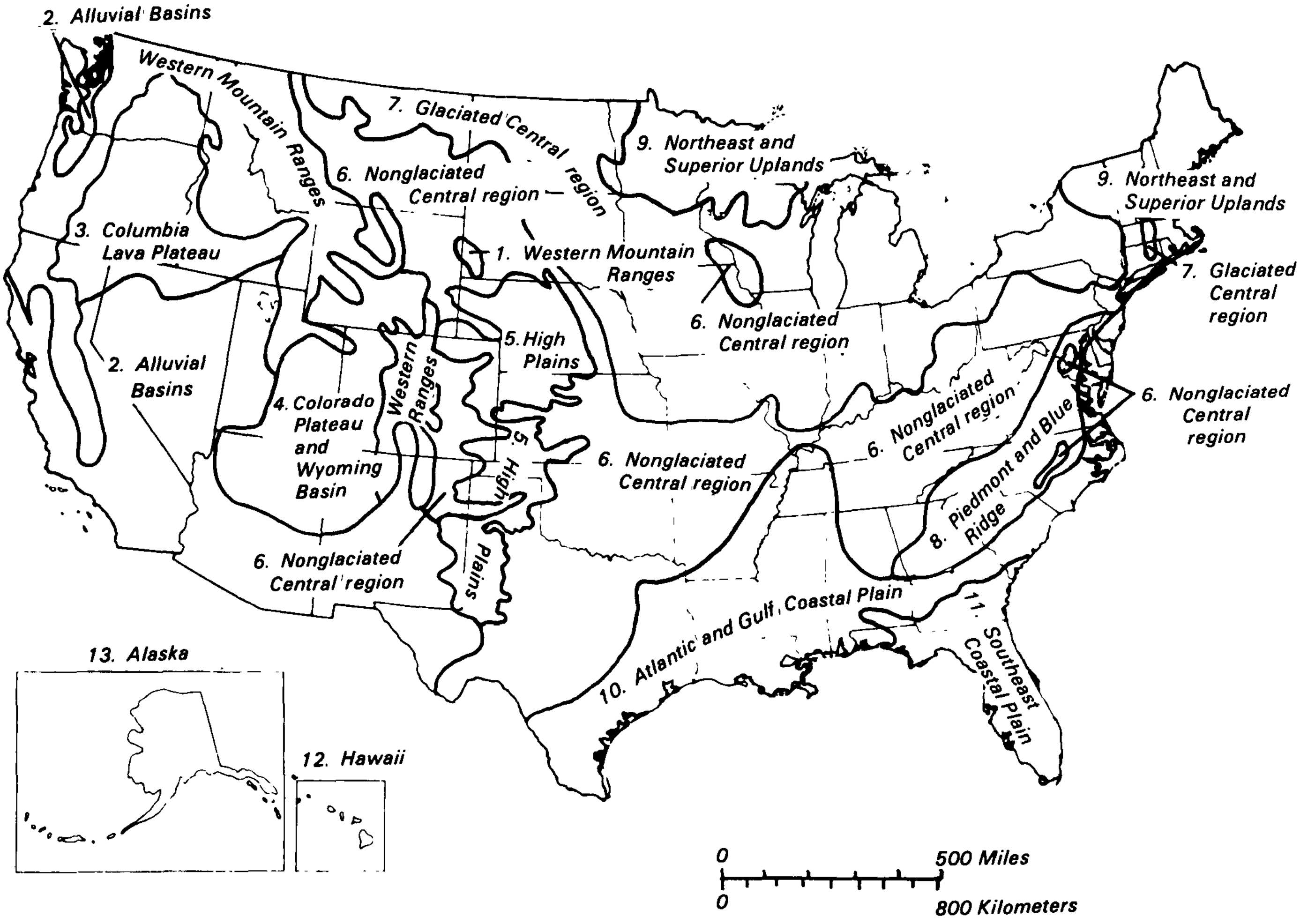

Figure 1. Ground-water regions of the United States (After Heath, 1984).

Hawaii

(12C) Volcanic Uplands

This hydrogeologic setting is characterized by moderately rolling topography, at medium elevations, and rich, dark, soils developed from the basaltic bedrock. The soils are permeable, rainfall is high, and recharge is high. Bedrock is composed primarily of alternating extrusive basaltic lava flows and interlayered weathered zones formed between flows. Ground water occurs at moderate to deep depths, and aquifer yield is controlled by fracture zones, vesicular zones (both primarily cooling features) and the inter-flow weathered zones. Hydraulic conductivity is high. As with other settings in Hawaii, heavy pumping stresses often result in salt-water intrusion. This is a reflection of the fact that each island is surrounded by and underlain by salt water, with the fresh water occurring in a lenticular body that floats on the salt water. Ground water yield is therefore limited quite specifically to the amount of water recharged annually

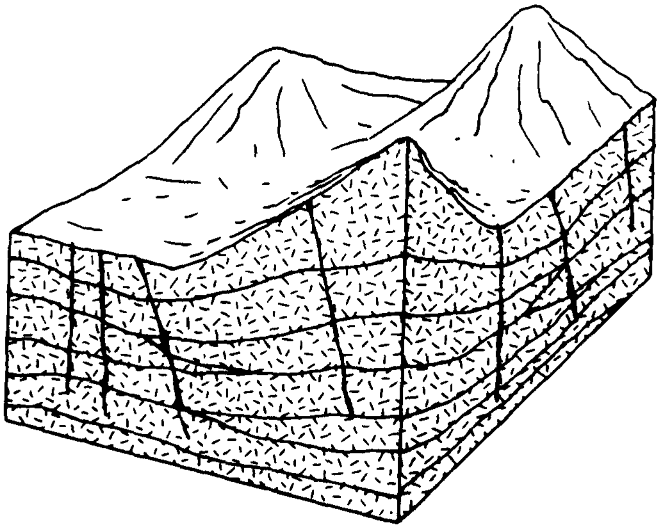

Figure 2. *Format of hydrogeological setting.*

The DRASTIC factors represent measurable parameters for which data are generally available from a variety of sources without detailed reconnaissance. Sources of this information are listed in Table 1.

Each DRASTIC factor has been evaluated with respect to each other to determine the relative importance of each factor. Each DRASTIC factor has been assigned a relative weight ranging from 1 to 5 (Table 2), with the most significant factors having a weight of 5 and the least significant a weight of 1. These weights are constant and may not be changed.

A special case for the DRASTIC Index was developed for agricultural areas where the application of pesticides are a concern. Pesticide DRASTIC was created to address the important processes which affect the fate and transport of pesticides into the subsurface. The weights assigned for each factor have been modified to reflect the potential impacts of pesticide application on ground water (Table 3).

Each DRASTIC factor has been divided into either ranges or significant media types which have an impact on pollution potential. Each range or media has then been evaluated with respect to each other to determine the relative significance of each range or media with respect to pollution potential. These ranges and media have been assigned a rating of from 1 to 10, with the most significant range or media having a rating of 10, and the least significant a rating of 1 (Tables 4-10).

Once the DRASTIC Index has been computed, it is possible to identify areas which are more likely to be susceptible to ground-water contamination relative to one another. The higher the DRASTIC Index, the greater the ground-water pollution potential. A DRASTIC Index calculated for one setting may then be compared to values obtained in other settings in the same region or in a different region.

Hydrogeologic settings are combined with DRASTIC Indexes to create mappable units which present a "picture" of the geologic and hydrogeologic conditions of an area. To fully demonstrate and test the system, DRASTIC was applied to 10 counties across the United States representing a diversity of hydrogeologic conditions including:

1. Cumberland County, Maine;
2. Finney County, Kansas;
3. Gillespie County, Texas;
4. Greenville County, South Carolina;
5. Lake County, Florida;
6. Minidoka County, Idaho;
7. New Castle County, Delaware;
8. Pierce County, Washington;
9. Portage County, Wisconsin; and
10. Yolo County, California.

These counties were chosen to represent both rural and urban areas and to exemplify both an abundance and scarcity of available hydrogeologic data. Pollution potential maps showing hydrogeologic settings and DRASTIC Indexes were manually drawn for each county. To assist in map readability, each demonstration map was color-coded using the DRASTIC Index. A national color code scheme was developed based on a simplified statistical evaluation of frequency of Index occurrence. The colors of the spectrum were chosen to show the levels of relative vulnerability to pollution. The warm colors indicate areas with potentially greater problems and cool colors indicate areas with lower susceptibility to ground-water pollution. Figure 3 illustrates the superposition of the national color code on a portion of the pollution potential map for Yolo County, California. Various screens have been chosen to simulate the color variations on the map.

Conclusion

The system presents a simple and easy-to-use approach to assess the ground-water pollution potential of any area. Although the final system appears simplistic, the system actually includes many complex concepts and relationships. Before an attempt is made to make full use of this system, the user must develop an appreciation for the complexity of evaluating ground-water pollution potential. It is not necessary to understand every concept in detail, but the

Table 1. *Sources of Hydrogeologic Information*

Source	*Depth to Water*	*Net Recharge*	*Aquifer Media*	*Soil Media*	*Topography*	*Impact of the Vadose Media*	*Hydraulic Conductivi of the Aquifer*
U.S. Geological Survey	X	X	X		X	X	X
State Geological Surveys	X	X	X			X	X
State Department of Natural/Water Resources	X	X	X			X	X
U.S. Department of Agriculture-Soil Conservation Service		X		X	X		
State Department of Environmental Protection	X	X	X			X	X
Clean Water Act "208" and other Regional Planning Authorities	X	X	X			X	X
County and Regional Water Supply Agencies and Companies (private water suppliers)	X		X			X	X
Private Consulting Firms (hydrogeologic, engineering)	X		X			X	X
Related Industry Studies (mining, well drilling, quarrying, etc.)	X		X			X	
Professional Associations (Geological Society of America, National Water Well Association, American Geophysical Union)	X	X	X			X	X
Local Colleges and Universities (Departments of Geology, Earth Sciences, Civil Engineering)	X	X	X			X	X
Other Federal/State Agencies (Army Corps of Engineers, National Oceanic and Atmospheric Administration	X	X	X			X	

greater the depth of understanding, the more useful the system becomes.

DRASTIC produces mappable results that provide a basis for the comparative evaluation of areas with respect to the potential for ground-water pollution. DRASTIC should not be used for site specific investigations, but is best applied on a regional basis to areas greater than 100 acres in size. DRASTIC is designed to assist individuals with resource allocation and prioritization of many types of ground-water related activities as well as to provide a practical educational tool.

Table 2. *Assigned Weights for DRASTIC Features*

Feature	*Weight*
Depth to Water	*5*
Net Recharge	*4*
Aquifer Media	*3*
Soil Media	*2*
Topography	*1*
Impact of the Vadose Zone Media	*5*
Hydraulic Conductivity of the Aquifer	*3*

Table 3. *Assigned Weights for Pesticide DRASTIC Features*

Feature	*Pesticide Weight*
Depth to Water	*5*
Net Recharge	*4*
Aquifer Media	*3*
Soil Media	*5*
Topography	*3*
Impact of the Vadose Zone Media	*4*
Hydraulic Conductivity of the Aquifer	*2*

Table 4. *Ranges and Ratings for Depth to Water*

Depth to Water (Feet)	
Range	Rating
0-5	10
5-15	9
15-30	7
30-50	5
50-75	3
75-100	2
100+	1
Weight: 5	Pesticide Weight: 5

Table 5. *Ranges and Ratings for Net Recharge*

Net Recharge (Inches)	
Range	Rating
0-2	1
2-4	3
4-7	6
7-10	8
10+	9
Weight: 4	Pesticide Weight: 4

Table 6. *Ranges and Ratings for Aquifer Media*

Aquifer Media		
Range	Rating	Typical Rating
Massive Shale	1-3	2
Metamorphic/Igneous	2-5	3
Weathered Metamorphic/Igneous	3-5	4
Glacial Till	4-6	5
Bedded Sandstone, Limestone and Shale Sequences	5-9	6
Massive Sandstone	4-9	6
Massive Limestone	4-9	6
Sand and Gravel	4-9	8
Basalt	2-10	9
Karst Limestone	9-10	10
Weight: 3		Pesticide Weight: 3

Table 7. *Ranges and Ratings for Soil Media*

Soil Media	
Range	Rating
Thin or Absent	10
Gravel	10
Sand	9
Peat	8
Shrinking and/or Aggregated Clay	7
Sandy Loam	6
Loam	5
Silty Loam	4
Clay Loam	3
Muck	2
Nonshrinking and Nonaggregated Clay	1
Weight: 2	Pesticide Weight: 5

Table 8. *Ranges and Ratings for Topography*

Topography (Percent Slope)	
Range	Rating
0-2	10
2-6	9
6-12	5
12-18	3
18+	1
Weight: 1	Pesticide Weight: 3

Table 9. *Ranges and Ratings for Impact of the Vadose Zone Media*

Impact of the Vadose Zone Media		
Range	Rating	Typical Rating
Confining Layer	1	1
Silt/Clay	2-6	3
Shale	2-5	3
Limestone	2-7	6
Sandstone	4-8	6
Bedded Limestone, Sandstone, Shale	4-8	6
Sand and Gravel with Significant Silt and Clay	4-8	6
Metamorphic/Igneous	2-8	4
Sand and Gravel	6-9	8
Basalt	2-10	9
Karst Limestone	8-10	10
Weight: 5	Pesticide Weight: 4	

Table 10. *Ranges and Ratings for Hydraulic Conductivity*

Hydraulic Conductivity (gpd/ft^2)	
Range	Rating
1-100	1
100-300	2
300-700	4
700-1000	6
1000-2000	8
2000+	10
Weight: 3	Pesticide Weight: 2

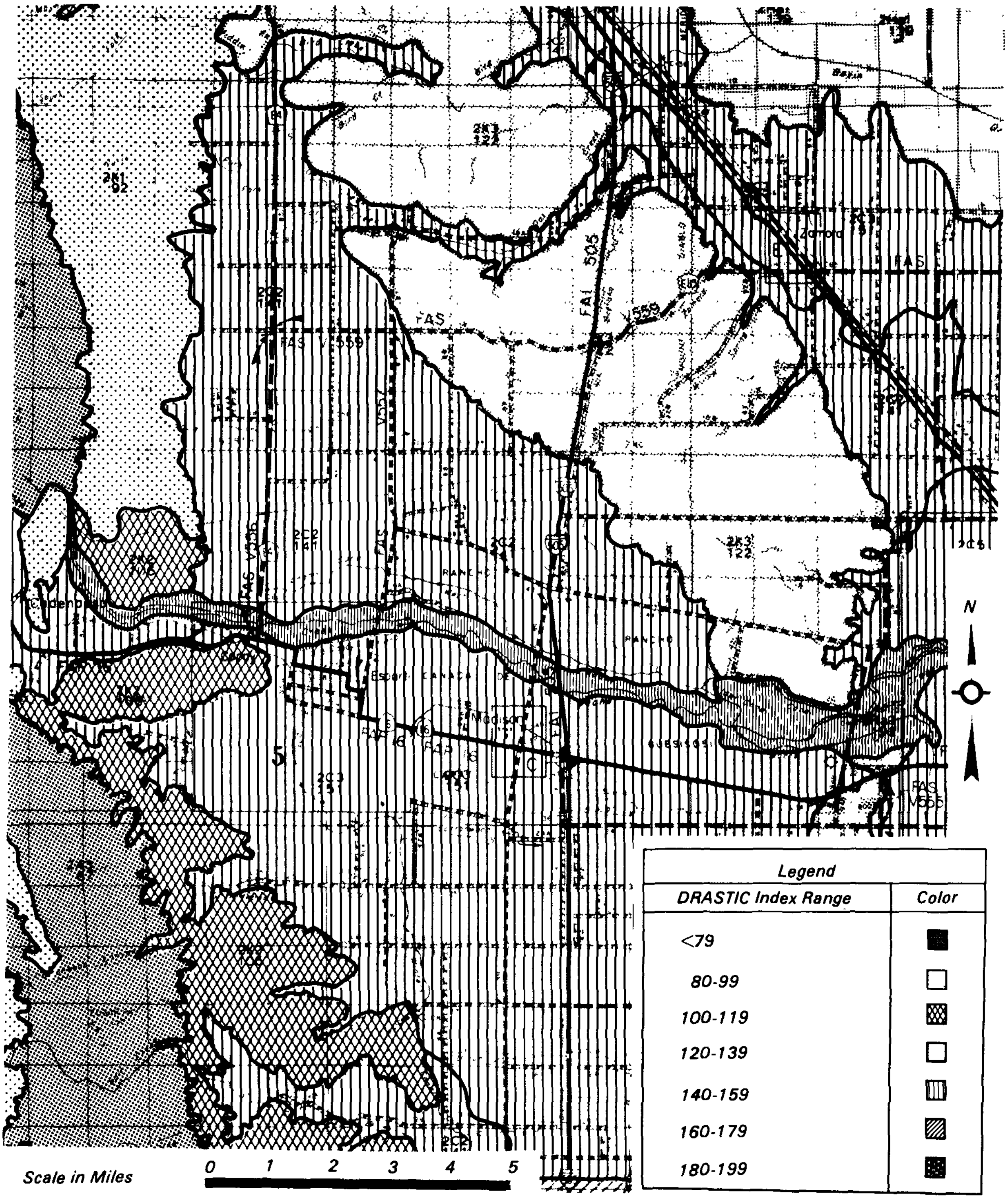

Figure 3. Pollution potential map for a portion of Yolo County, California, showing the superposition of the national color code.

Linda Aller, Truman Bennett, Jay H. Lehr, Rebecca Petty, and Glen Hackett are with National Water Well Association, Dublin, OH 43017.
Jerry Thornhill *is the EPA Project Officer (see below)*

The complete report, entitled "DRASTIC: A Standardized System for Evaluating Ground Water Pollution Potential Using Hydrogeologic Settings," (Order No. PB 87-213 914/AS; Cost: $48.95, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

The EPA Project Officer can be contacted at:

Robert S. Kerr Environmental Research Laboratory
U.S. Environmental Protection Agency
Ada, OK 74820

United States
Environmental Protection
Agency

Center for Environmental Research
Information
Cincinnati OH 45268

Official Business
Penalty for Private Use $300

EPA/600/S2-87/035