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# Pesticide Occurrence in Groundwater in Areas of High-Density Row Crop Production in Alabama, 2009

Open-File Report 2011–1102

U.S. Department of the Interior
U.S. Geological Survey

**Cover photograph.** Cotton field in northern Alabama by Amy C. Gill, USGS.

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**U.S. Department of the Interior**
**U.S. Geological Survey**

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KEN SALAZAR, Secretary

**U.S. Geological Survey**
Marcia K. McNutt, Director

U.S. Geological Survey, Reston, Virginia: 2011



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# Conversion Factors and Datum

[Inch/Pound to SI]

| Multiply | By | To obtain |
|---|---|---|
| | Length | |
| foot (ft) | 0.3048 | meter (m) |
| mile (mi) | 1.609 | kilometer (km) |
| | Area | |
| acre | 4,047 | square meter ($m^2$) |
| square foot ($ft^2$) | 929.0 | square centimeter ($cm^2$) |
| square foot ($ft^2$) | 0.09290 | square meter ($m^2$) |
| square inch ($in^2$) | 6.452 | square centimeter ($cm^2$) |
| section (640 acres or 1 square mile) | 259.0 | square hectometer ($hm^2$) |
| square mile ($mi^2$) | 259.0 | hectare (ha) |
| square mile ($mi^2$) | 2.590 | square kilometer ($km^2$) |
| | Volume | |
| gallon (gal) | 3.785 | liter (L) |
| gallon (gal) | 0.003785 | cubic meter ($m^3$) |

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C = (°F - 32) / 1.8$$

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

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## Abstract

High-density row crop production occurs in three areas of Alabama that are underlain by productive aquifers, northern Alabama, southeastern Alabama, and Baldwin County in southwestern Alabama. The U.S. Geological Survey collected five groundwater samples from each of these three areas during 2009 for analysis of selected pesticides. Results of these analyses showed detections for 37 of 152 analytes. The three most frequently detected compounds were atrazine, 2-Chloro-4-isopropylamino-6-amino-triazine (CIAT), and metolachlor. The highest concentration for any analyte was 4.08 micrograms per liter for metolachlor.

## Introduction

Agriculture is an important part of the economy for the State of Alabama. In 2002, more than 8.9 million acres in Alabama were used for agriculture and more than $3.2 billion in agricultural products were sold in the State (U.S. Department of Agriculture, 2002). Field crops and miscellaneous row crops contributed more than $446 million in crop production. Agricultural pesticides, including insecticides, herbicides, and fungicides, improve crop production by limiting losses to noxious insects, weeds, and fungi. More than 2.8 million acres in Alabama were treated with some form of pesticide during 2007 (U.S. Department of Agriculture, 2007b). The widespread use of pesticides to support agriculture makes responsible management of agricultural pesticide use in the State of Alabama a priority, and monitoring of the occurrence of pesticides in groundwater is an important first step in management activities.

Three areas in the State of Alabama with high-density row crop production that are underlain by productive aquifers were selected for this study: northern Alabama (Limestone, Madison, Colbert, Lawrence, Morgan, and Jackson Counties), southeastern Alabama (Houston, Henry, and Geneva Counties), and Baldwin County in southwestern Alabama (fig. 1).

### Purpose and Scope

This report describes the results from the initial sampling effort of a study the U.S. Geological Survey (USGS) Alabama Water Science Center is conducting, in cooperation with the Pesticide Management Branch of the Alabama Department of Agriculture and Industries, to evaluate detection frequencies and concentrations of pesticides in groundwater near areas of high-density row crop production in Alabama. Fifteen wells were sampled during this study; five wells were sampled in each of the three main agricultural areas (figs. 2–4; table 1). Data collected for this study will be directly comparable to data collected from pesticide studies across the nation and will increase the understanding of the relation between agricultural land use and groundwater quality.

## Methods

Fifteen wells, five in each of the three main agricultural areas, were sampled during this study (figs. 2–4; table 1). The wells were selected based upon several factors, including proximity to row crops, well depth, accessibility, and the existence of comparable pesticide data from previous studies. Domestic water-supply or irrigation wells were sampled in southeastern and southwestern Alabama. This study benefitted from the USGS National Water Quality Assessment (NAWQA) Program by utilizing 5 of the 30 wells that were previously installed in the Lower Tennessee River Basin (LTEN) to monitor water-quality trends in areas of high-density row-crop production in shallow groundwater for a variety of analytes, including pesticides (Kingsbury, 2003).

Groundwater samples were analyzed for temperature, specific conductance, dissolved oxygen, pH, and pesticides. Sampling procedures, field methods, and equipment decontamination were consistent with standard USGS procedures set forth in the USGS National Field Manual (U.S. Geological Survey, variously dated). Wells were purged of at least three casing volumes of water and (or) until field measurements

of temperature, pH, specific conductance, and dissolved oxygen were stable for three consecutive readings at 5-minute intervals prior to sample collection.

Samples from all 15 wells were analyzed for 87 filtered pesticides and pesticide degradates by using capillary-column gas chromatography/mass spectrometry with selected-ion monitoring (National Water Quality Laboratory (NWQL) schedule 2033; Zaugg and others, 1995; Sandstrom and others, 2001; table 2). Schedule 2033 samples were collected during April 2009 from wells 1, 2, 4, and 5 as part of the ongoing NAWQA-LTEN. Schedule 2033 samples were collected during June 2009 from wells, 3, 6, 7, 8, 9, 10, 11, 12, 13, 14, and 15. In addition, samples collected from wells 1, 2, 3, 4, and 5, during June 2009 were analyzed for 65 polar pesticides and metabolites by using high-performance liquid chromatography/mass spectrometry (NWQL schedule 2060; Furlong and others, 2001; table 3) in order to provide information on the occurrence of a greater number of pesticides not included in the 2033 schedule. Samples for both pesticide schedules were filtered through 0.7 micron glass fiber filters and shipped on ice overnight to the USGS NWQL in Denver, Colorado. Once at the NWQL, samples for both schedules were extracted onto solid-phase extraction columns prior to analysis.

The bias and variability associated with environmental samples must be known to accurately interpret water-quality data (U.S. Geological Survey, 2006). Field blanks are used to verify that equipment-cleaning procedures are valid and that environmental bias is limited. Pesticide analytes tested in samples collected during the current study were not detected in two field equipment blanks, which were collected using the same equipment and sampling protocols during two separate studies prior to and after this study (Amy C. Gill, U.S. Geological Survey, written commun., 2009). Field replicates are collected to check for variability from both laboratory and field bias. Analyses of one field replicate collected for well 10 showed no variability for that set of samples.

# Results

Results of field measurements and pesticide analyses for NWQL schedule 2033 are shown in table 4. The three most frequently detected compounds for schedule 2033 in the 15 wells were the herbicides atrazine (11 of 15 wells); 2-Chloro-4-isopropylamino-6-amino-s-triazine (CIAT), an atrazine degradation byproduct (11 of 15 wells); and metolachlor (8 of 15 wells). The wells with the highest numbers of pesticides detected for schedule 2033 were wells 3, 5, 1, and 6 with 17, 13, 8 and 7 compounds detected, respectively (table 4). The highest concentration for an NWQL schedule 2033 analyte was 4.08 micrograms per liter (µg/L) for the herbicide metolachlor, which was detected in well 15 located in Baldwin County.

Samples analyzed by NWQL schedule 2060 were only collected at the five wells in northern Alabama. Results of these analyses are shown in table 5. All five of the northern Alabama wells had detections of the herbicides fluometuron and norflurazon, which were not analyzed in the two southern areas (table 5). The highest concentration for NWQL schedule 2060 was 0.82 µg/L for norfurazon. The wells with the greatest number of detections for NWQL schedule 2060 were wells 1 and 2 with 11 and 8 detections, respectively.

# Acknowledgments

The author would like to acknowledge and thank the well owners for their enthusiasm, interest, and participation in the study. Mr. Ray Marler and Mr. Vernon Wiggins of the Alabama Department of Agriculture and Industries were instrumental in locating wells in Baldwin County and southeastern Alabama. Their relationships with local farmers and citizens were critical for the successful selection of wells in these areas.

## Selected References

Furlong, E.T., Anderson, B.D., Werner, S.L., Soliven, P.P., Coffey, L.J., and Burkhardt, M.R., 2001, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of pesticides in water by graphitized carbon-based solid-phase extraction and high-performance liquid chromatography/mass spectrometry: U.S. Geological Survey Water-Resources Investigations Report 01–4134, 73 p.

Kingsbury, J.A., 2003, Shallow ground-water quality in agricultural area of northern Alabama and middle Tennessee, 2000–2001: U.S. Geological Survey Water-Resources Investigations Report 03–4181, 38 p.

Kingsbury, J.A., and Shelton, J.M., 2002, Water quality of the Mississippian carbonate aquifer in parts of middle Tennessee and northern Alabama, 1999: U.S. Geological Survey Water-Resources Investigations Report 02–4083, 36 p.

Sandstrom, M.W., Stroppel, M.E., Foreman, W.T., and Schroeder, M.P., 2001, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of moderate-use pesticides and selected degradates in water by C-18 solid-phase extraction and gas chromatography/mass spectrometry: U.S. Geological Survey Water-Resources Investigations Report 01–4098, 70 p.

U.S. Department of Agriculture, 2002, The census of agriculture, 2002 census publications, Alabama, accessed June 30, 2008, at *http://www.agcensus.usda.gov/Publications/2002/County_Profiles/Alabama/*.

U.S. Department of Agriculture, 2007a, The census of agriculture, 2007 census publications, Alabama, Table 45. Fertilizers and chemicals—2007 and 2002, accessed February 24, 2010, at *http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_1_State_Level/Alabama/*.

U.S. Department of Agriculture, 2007b, The census of agriculture, 2007 census publications, Desktop Data Query Tool 1.02, accessed August 26, 2010, at *http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Desktop_Application/index.asp*.

U.S. Geological Survey, variously dated, National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chaps. A1–A9, available online at *http://pubs.water.usgs.gov/twri9A*.

Zaugg, S.D., Sandstrom, M.W., Smith, S.G., and Fehlberg, K.M., 1995, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of pesticides in water by C-18 solid-phase extraction and capillary-column gas chromatography/mass spectrometry with selected-ion monitoring: U.S. Geological Survey Open-File Report 95–181, 49 p.

# Figures and Tables

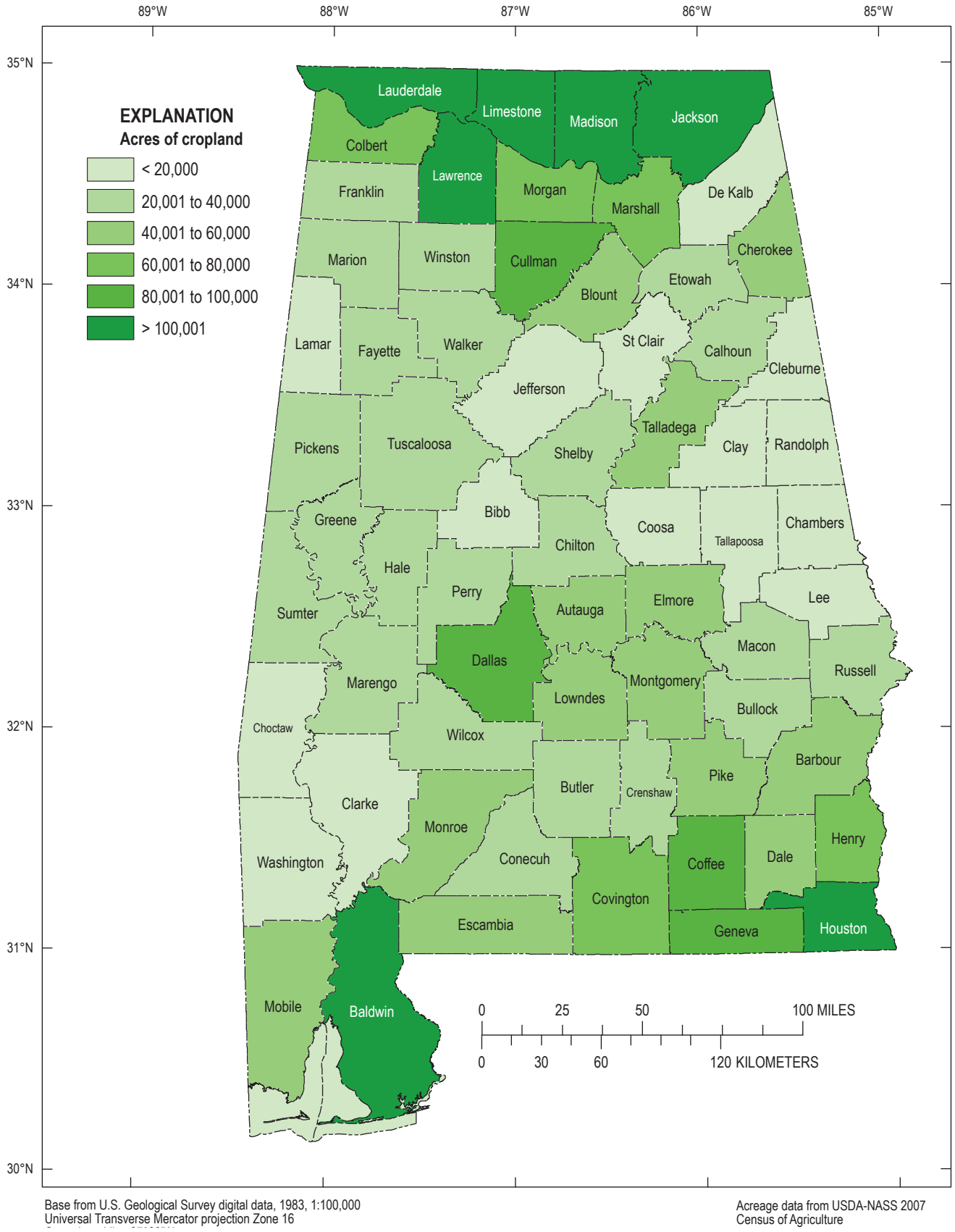


**Figure 1.** Cropland acreage in Alabama, 2007.

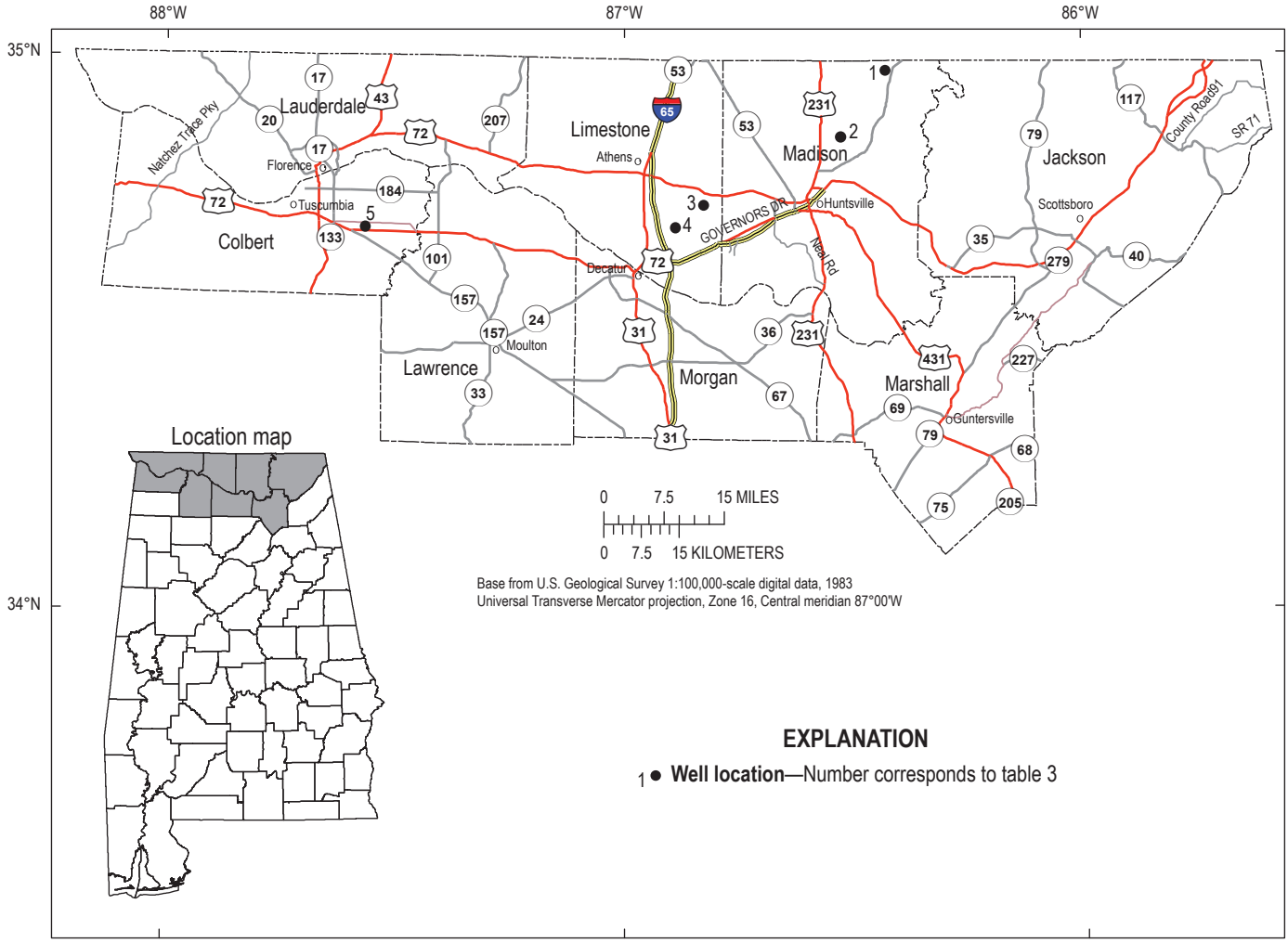


**Figure 2.** Location of wells in Northern Alabama.

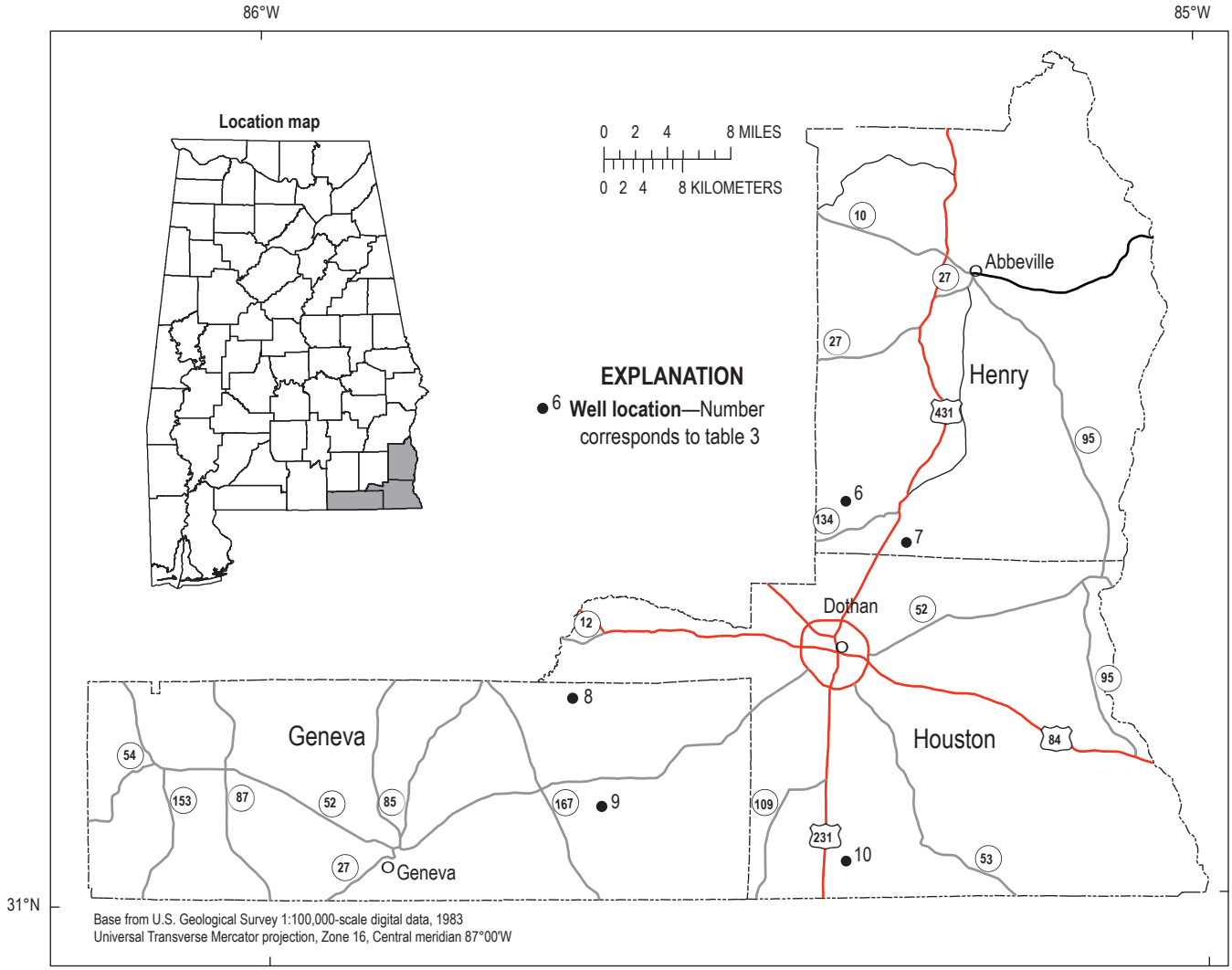


**Figure 3.** Location of wells in Southeastern Alabama.

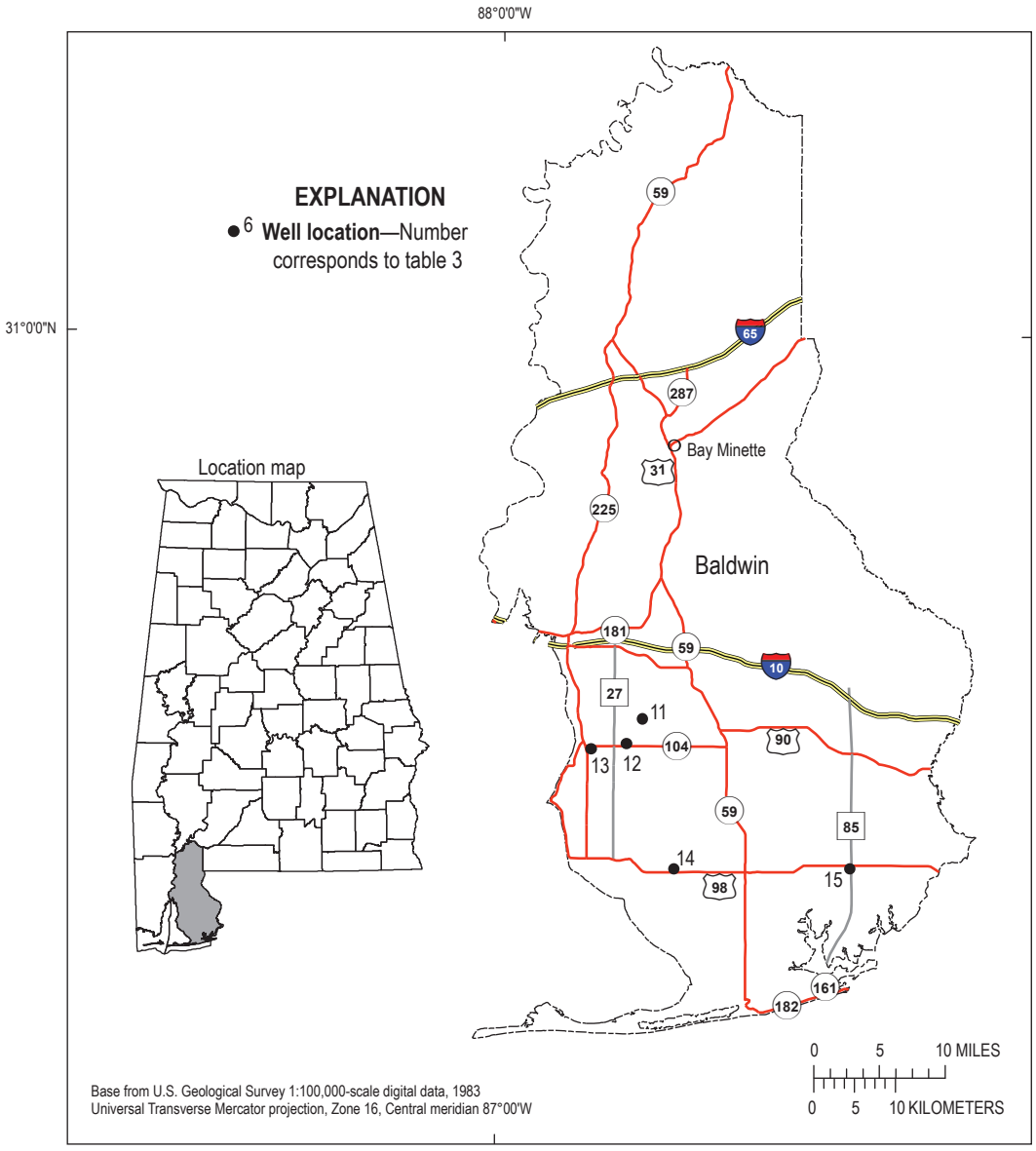


**Figure 4.** Location of wells in Baldwin County, Alabama.

**Table 1.** Selected well characteristics for study wells in Alabama.

[USGS, U.S. Geological Survey; °, degree; ', minute; ", second; M, monitor; D, domestic; I, irrigation; U, unused]

| Map number (figs. 2–4) | USGS station number | Latitude | Longitude | County | Well depth (feet) | Use of well |
|---|---|---|---|---|---|---|
| 1 | 345822086254001 | 34°58'21.8" | 86°25'40.5" | Madison | 50 | M |
| 2 | 345112086313401 | 34°51'12.4" | 86°31'34.2" | Madison | 35 | M |
| 3 | 344124086531401 | 34°41'24.2" | 86°53'13.6" | Limestone | 24 | M |
| 4 | 344348086493401 | 34°43'48.2" | 86°49'34" | Limestone | 53 | M |
| 5 | 344131087335201 | 34˚41'30.9" | 87°33'52. 2" | Colbert | 53 | M |
| 6 | 312143085230301 | 31°21'43" | 85°23'03" | Henry | 105 | D |
| 7 | 311928085191101 | 31°19'28" | 85°19'11" | Henry | 231 | D |
| 8 | 311048085403201 | 31°10'48" | 85°40'32" | Geneva | 310 | D |
| 9 | 310453085383001 | 31°04'53" | 85°38'30" | Geneva | 140 | D |
| 10 | 310153085225901 | 31°01'53" | 85°22'59" | Houston | 95 | D |
| 11 | 303432087485501 | 30°34'32" | 87°48'55" | Baldwin | 110 | D |
| 12 | 303252087500801 | 30°32'52" | 87°50'08" | Baldwin | 140 | I |
| 13 | 303231087525801 | 30°32'31" | 87°52'58" | Baldwin | 130 | I |
| 14 | 302434087462601 | 30°24'34" | 87°46'26" | Baldwin | 65 | U |
| 15 | 302438087325801 | 30°24'38" | 87°32'58" | Baldwin | 45 | D |

**Table 2.** List of chemical compounds and minimum reporting levels for U.S. Geological Survey National Water Quality Laboratory Schedule 2033.

[CAS, chemical abstract service; table contains CAS Registry Numbers®, a Registered Trademark of the American Chemical Society; CAS recommends the verification of CASRNs through CAS Client Services℠; µg/L, microgram per liter; bold type indicates at least one detection; —, no CAS number]

| Compound | CAS number | Minimum reporting level, in µg/L |
|---|---|---|
| 1-Naphthol | 90-15-3 | 0.036 |
| 2,6-Diethylaniline | 579-66-8 | 0.006 |
| **2-Chloro-2,6-diethylacetanilide** | 6967-29-9 | 0.01 |
| **2-Chloro-4-isopropylamino-6-amino-s-triazine (CIAT)** | 6190-65-4 | 0.014 |
| 2-Ethyl-6-methylaniline | 24549-06-2 | 0.0098 |
| **3,4-Dichloroaniline** | 95-76-1 | 0.0042 |
| 3,5-Dichloroaniline | 626-43-7 | 0.003 |
| 4-Chloro-2-methylphenol | 1570-64-5 | 0.0032 |
| Acetochlor | 34256-82-1 | 0.01 |
| **Alachlor** | 15972-60-8 | 0.008 |
| alpha-Endosulfan | 959-98-8 | 0.006 |
| **Atrazine** | 1912-24-9 | 0.007 |
| Azinphos-methyl | 86-50-0 | 0.12 |
| Azinphos-methyl-oxon | 961-22-8 | 0.042 |
| **Benfluralin** | 1861-40-1 | 0.014 |
| Carbaryl | 63-25-2 | 0.06 |
| **Carbofuran** | 1563-66-2 | 0.06 |
| Chlorpyrifos | 2921-88-2 | 0.01 |
| **Chlorpyrifos, oxygen analog** | 5598-15-2 | 0.05 |
| *cis*-Permethrin | 61949-76-6 | 0.014 |
| ***cis*-Propiconazole** | 60207-90-1 | 0.006 |
| Cyanazine | 21725-46-2 | 0.022 |
| Cyfluthrin | 68359-37-5 | 0.016 |
| Cypermethrin | 52315-07-8 | 0.02 |
| **Dacthal** | 1861-32-1 | 0.0076 |
| Desulfinylfipronil | — | 0.012 |
| Desulfinylfipronil amide | — | 0.029 |
| Diazinon | 333-41-5 | 0.005 |
| Diazinon, oxygen analog | 962-58-3 | 0.006 |
| Dichlorvos | 62-73-7 | 0.02 |
| Dicrotophos | 141-66-2 | 0.08 |
| Dieldrin | 60-57-1 | 0.009 |
| Dimethoate | 60-51-5 | 0.006 |
| Disulfoton | 298-04-4 | 0.04 |
| **Disulfoton sulfone** | 6-5-2497 | 0.013 |
| Endosulfan sulfate | 1031-07-8 | 0.014 |
| EPTC | 759-94-4 | 0.002 |
| Ethion | 563-12-2 | 0.008 |
| Ethion monoxon | 17356-42-2 | 0.021 |
| Ethoprophos | 13194-48-4 | 0.016 |
| Fenamiphos | 22224-92-6 | 0.03 |
| Fenamiphos sulfone | 31972-44-8 | 0.053 |
| Fenamiphos sulfoxide | 31972-43-7 | 0.08 |
| Fipronil | 120068-37-3 | 0.018 |
| Fipronil sulfide | 120067-83-6 | 0.013 |
| Fipronil sulfone | 120068-36-2 | 0.024 |
| Fonofos | 944-22-9 | 0.0044 |
| Hexazinone | 51235-04-2 | 0.008 |
| Iprodione | 36734-19-7 | 0.014 |
| Isofenphos | 25311-71-1 | 0.006 |
| lambda-Cyhalothrin | 91465-08-6 | 0.01 |
| Malaoxon | 1634-78-2 | 0.08 |
| Malathion | 121-75-5 | 0.016 |
| **Metalaxyl** | 57837-19-1 | 0.007 |
| Methidathion | 950-37-8 | 0.006 |
| **Metolachlor** | 51218-45-2 | 0.014 |
| **Metribuzin** | 21087-64-9 | 0.012 |
| **Molinate** | 2212-67-1 | 0.0026 |
| Myclobutanil | 88671-89-0 | 0.01 |
| Oxyfluorfen | 42874-03-3 | 0.01 |
| Paraoxon-methyl | 950-35-6 | 0.01 |
| Parathion-methyl | 298-00-0 | 0.008 |
| Pendimethalin | 40487-42-1 | 0.012 |
| Phorate | 298-02-2 | 0.02 |
| Phorate oxygen analog | 2600-69-3 | 0.027 |
| Phosmet | 732-11-6 | 0.034 |
| Phosmet oxon | 3735-33-9 | 0.051 |
| **Prometon** | 1610-18-0 | 0.012 |
| **Prometryn** | 7287-19-6 | 0.006 |
| Propanil | 709-98-8 | 0.01 |
| Propargite | 2312-35-8 | 0.02 |
| Propyzamide | 23950-58-5 | 0.0036 |
| **Simazine** | 122-34-9 | 0.006 |
| Tebuconazole | 107534-96-3 | 0.02 |
| **Tebuthiuron** | 34014-18-1 | 0.028 |
| Tefluthrin | 79538-32-2 | 0.01 |
| Terbufos | 13071-79-9 | 0.018 |
| Terbufos oxygen analog sulfone | 56070-15-6 | 0.045 |
| **Terbuthylazine** | 5915-41-3 | 0.006 |
| **Thiobencarb** | 28249-77-6 | 0.016 |
| ***trans*-Propiconazole** | 60207-90-1 | 0.02 |
| Tribufos | 78-48-8 | 0.018 |
| Trifluralin | 1582-09-8 | 0.018 |

**Table 3.** List of chemical compounds and minimum reporting levels for U.S. Geological Survey National Water Quality Laboratory Schedule 2060.

[CAS, chemical abstract service; table contains CAS Registry Numbers®, a Registered Trademark of the American Chemical Society; CAS recommends the verification of CASRNs through CAS Client Services℠; µg/L, microgram per liter; bold type indicates at least one detection; —, no CAS number]

| Compound | CAS number | Minimum reporting level, in µg/L |
|---|---|---|
| 2,4-D | 94-75-7 | 0.06 |
| 2,4-D methyl ester | 1928-38-7 | 0.2 |
| 2,4-D plus 2,4-D methyl ester | — | 0.06 |
| 2,4-DB | 94-82-6 | 0.02 |
| **2-Chloro-4-isopropylamino-6-amino-s-triazine (CIAT)** | 6190-65-4 | 0.06 |
| **2-Chloro-6-ethylamino-4-amino-s-triazine (CEAT)** | 1007-28-9 | 0.06 |
| **2-Hydroxy-4-isopropylamino-6-ethylamino-s-triazine (OIET)** | 2163-68-0 | 0.06 |
| 3(4-Chlorophenyl)-1-methyl urea | 5352-88-5 | 0.06 |
| 3-Hydroxycarbofuran | 16655-82-6 | 0.04 |
| Acifluorfen | 50594-66-6 | 0.04 |
| Aldicarb | 116-06-3 | 0.12 |
| **Aldicarb sulfone** | 1646-88-4 | 0.08 |
| **Aldicarb sulfoxide** | 1646-87-3 | 0.06 |
| **Atrazine** | 1912-24-9 | 0.04 |
| Bendiocarb | 22781-23-3 | 0.04 |
| Benomyl | 17804-35-2 | 0.06 |
| Bensulfuron-methyl | 83055-99-6 | 0.06 |
| Bentazon | 25057-89-0 | 0.06 |
| Bromacil | 314-40-9 | 0.06 |
| Bromoxynil | 1689-84-5 | 0.12 |
| Caffeine | 58-08-2 | 0.08 |
| Carbaryl | 63-25-2 | 0.04 |
| Carbofuran | 1563-66-2 | 0.04 |
| Chloramben, methyl ester | 7286-84-2 | 0.1 |
| Chlorimuron-ethyl | 90982-32-4 | 0.08 |
| Clopyralid | 1702-17-6 | 0.06 |
| Cycloate | 1134-23-2 | 0.04 |
| Dacthal monoacid | 887-54-7 | 0.04 |
| Dicamba | 1918-00-9 | 0.04 |
| Dichlorprop | 120-36-5 | 0.04 |
| Dinoseb | 88-85-7 | 0.04 |
| Diphenamid | 957-51-7 | 0.04 |
| **Diuron** | 330-54-1 | 0.04 |
| Fenuron | 101-42-8 | 0.06 |
| Flumetsulam | 98967-40-9 | 0.06 |
| **Fluometuron** | 2164-17-2 | 0.04 |
| Imazaquin | 81335-37-7 | 0.06 |
| Imazethapyr | 81335-77-5 | 0.06 |
| **Imidacloprid** | 138261-41-3 | 0.06 |
| Linuron | 330-55-2 | 0.04 |
| MCPA | 94-74-6 | 0.04 |
| MCPB | 94-81-5 | 0.2 |
| **Metalaxyl** | 57837-19-1 | 0.04 |
| Methiocarb | 2032-65-7 | 0.04 |
| **Methomyl** | 16752-77-5 | 0.12 |
| Metsulfuron methyl | 74223-64-6 | 0.14 |
| Neburon | 555-37-3 | 0.02 |
| Nicosulfuron | 111991-09-4 | 0.1 |
| **Norflurazon** | 27314-13-2 | 0.04 |
| Oryzalin | 19044-88-3 | 0.04 |
| Oxamyl | 23135-22-0 | 0.12 |
| Picloram | 1918-02-1 | 0.12 |
| Propham | 122-42-9 | 0.04 |
| Propiconazole | 60207-90-1 | 0.04 |
| Propoxur | 114-26-1 | 0.06 |
| Siduron | 1982-49-6 | 0.04 |
| Sulfometuron-methyl | 74222-97-2 | 0.06 |
| Tebuthiuron | 34014-18-1 | 0.06 |
| Terbacil | 5902-51-2 | 0.04 |
| Triclopyr | 55335-06-3 | 0.08 |

**Table 4.** Results of U.S. Geological Survey National Water Quality Laboratory schedule 2033 pesticide analyses for samples collected from groundwater wells in areas of high-density row crop production in Alabama, 2009.

[USGS, U.S. Geological Survey; E, estimated; —, missing; <, less than]

| USGS station number | Map number (figs. 2–4) | Date as month, day, year | Sample start time | Dissolved oxygen, water, unfiltered, milligrams per liter | Dissolved oxygen, water, unfiltered, percent of saturation | pH, water, unfiltered, field, standard units | Specific conductance, water, unfiltered, microsiemens per centimeter at 25 degrees Celsius |
|---|---|---|---|---|---|---|---|
| 345822086254001 | 1 | 4/27/2009 | 1300 | 8.3 | 90 | 4.7 | 71 |
| 345112086313401 | 2 | 4/27/2009 | 1630 | 7.3 | E82 | 6.8 | 223 |
| 344124086531401 | 3 | 6/11/2009 | 1645 | 7.7 | — | 6.6 | 146 |
| 344348086493401 | 4 | 4/28/2009 | 1615 | 7.1 | — | 6.9 | 274 |
| 344131087335201 | 5 | 4/28/2009 | 1330 | 5.3 | — | 7.3 | 291 |
| 312143085230301 | 6 | 6/10/2009 | 1155 | 8 | 90 | 4.3 | 154 |
| 311928085191101 | 7 | 6/10/2009 | 1500 | 2.7 | 31 | 7.9 | 235 |
| 311048085403201 | 8 | 6/11/2009 | 1355 | 4.2 | 48 | 7.2 | 201 |
| 310453085383001 | 9 | 6/11/2009 | 1010 | 9 | 103 | 4.5 | 100 |
| 310153085225901 | 10 | 6/12/2009 | 0920 | 7 | 81 | 7.8 | 206 |
| 303432087485501 | 11 | 6/16/2009 | 1305 | 9 | 103 | 4.2 | 170 |
| 303252087500801 | 12 | 6/16/2009 | 1445 | 8.8 | 100 | 4.7 | 138 |
| 303231087525801 | 13 | 6/17/2009 | 0930 | 8.5 | 98 | 5.7 | 27 |
| 302434087462601 | 14 | 6/17/2009 | 1230 | 8.7 | 98 | 4.4 | 132 |
| 302438087325801 | 15 | 6/17/2009 | 1555 | 9.1 | 105 | 4.3 | 164 |

| USGS station number | Map number (figs. 2–4) | Date as month, day, year | Sample start time | Temperature, water, degrees Celsius | 2-Chloro-2',6'-diethylacetanilide, water, filtered, recoverable, micrograms per liter | 2-Chloro-4-isopropylamino-6-amino-s-triazine, water, filtered, recoverable, micrograms per liter | 3,4-Dichloroaniline, water, filtered, recoverable, micrograms per liter |
|---|---|---|---|---|---|---|---|
| 345822086254001 | 1 | 4/27/2009 | 1300 | 18.4 | <0.01 | E0.054 | E0.005 |
| 345112086313401 | 2 | 4/27/2009 | 1630 | E20.3 | <0.01 | E0.124 | E0.004 |
| 344124086531401 | 3 | 6/11/2009 | 1645 | 20.9 | <0.01 | E0.213 | E0.006 |
| 344348086493401 | 4 | 4/28/2009 | 1615 | 18.3 | <0.01 | E0.008 | <0.004 |
| 344131087335201 | 5 | 4/28/2009 | 1330 | 18.7 | <0.01 | E0.598 | E0.014 |
| 312143085230301 | 6 | 6/10/2009 | 1155 | 21.2 | <0.01 | E0.018 | <0.004 |
| 311928085191101 | 7 | 6/10/2009 | 1500 | 21.8 | <0.01 | <0.014 | <0.004 |
| 311048085403201 | 8 | 6/11/2009 | 1355 | 22 | <0.01 | <0.014 | <0.004 |
| 310453085383001 | 9 | 6/11/2009 | 1010 | 21.6 | E0.005 | E0.004 | <0.004 |
| 310153085225901 | 10 | 6/12/2009 | 0920 | 21.8 | <0.01 | E0.005 | <0.004 |
| 303432087485501 | 11 | 6/16/2009 | 1305 | 21.9 | <0.01 | E0.007 | E0.004 |
| 303252087500801 | 12 | 6/16/2009 | 1445 | 21.3 | <0.01 | E0.008 | <0.004 |
| 303231087525801 | 13 | 6/17/2009 | 0930 | 22 | <0.01 | <0.014 | <0.004 |
| 302434087462601 | 14 | 6/17/2009 | 1230 | 21 | <0.01 | E0.005 | <0.004 |
| 302438087325801 | 15 | 6/17/2009 | 1555 | 22.5 | <0.01 | <0.014 | <0.004 |

**Table 4.** Results of U.S. Geological Survey National Water Quality Laboratory schedule 2033 pesticide analyses for samples collected from groundwater wells in areas of high-density row crop production in Alabama, 2009.—Continued

[USGS, U.S. Geological Survey; E, estimated; —, missing; <, less than]

| USGS station number | Map number (figs. 2–4) | Date as month, day, year | Sample start time | Alachlor, water, filtered, recoverable, micrograms per liter | Atrazine, water, filtered, recoverable, micrograms per liter | Benfluralin, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter | Carbofuran, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter |
|---|---|---|---|---|---|---|---|
| 345822086254001 | 1 | 4/27/2009 | 1300 | E0.007 | 0.085 | <0.014 | <0.06 |
| 345112086313401 | 2 | 4/27/2009 | 1630 | <0.008 | 0.08 | <0.014 | <0.06 |
| 344124086531401 | 3 | 6/11/2009 | 1645 | <0.008 | 0.25 | <0.014 | <0.06 |
| 344348086493401 | 4 | 4/28/2009 | 1615 | <0.008 | 0.011 | <0.014 | <0.06 |
| 344131087335201 | 5 | 4/28/2009 | 1330 | <0.008 | 0.225 | E0.011 | <0.06 |
| 312143085230301 | 6 | 6/10/2009 | 1155 | <0.008 | 0.025 | <0.014 | E0.007 |
| 311928085191101 | 7 | 6/10/2009 | 1500 | <0.008 | <0.007 | <0.014 | <0.06 |
| 311048085403201 | 8 | 6/11/2009 | 1355 | <0.008 | <0.007 | <0.014 | <0.06 |
| 310453085383001 | 9 | 6/11/2009 | 1010 | 0.064 | E0.005 | <0.014 | <0.06 |
| 310153085225901 | 10 | 6/12/2009 | 0920 | <0.008 | E0.006 | <0.014 | <0.06 |
| 303432087485501 | 11 | 6/16/2009 | 1305 | <0.008 | E0.006 | <0.014 | <0.06 |
| 303252087500801 | 12 | 6/16/2009 | 1445 | <0.008 | E0.005 | <0.014 | <0.06 |
| 303231087525801 | 13 | 6/17/2009 | 0930 | <0.008 | <0.007 | <0.014 | <0.06 |
| 302434087462601 | 14 | 6/17/2009 | 1230 | <0.008 | E0.004 | <0.014 | <0.06 |
| 302438087325801 | 15 | 6/17/2009 | 1555 | <0.008 | <0.007 | <0.014 | E0.005 |

| USGS station number | Map number (figs. 2–4) | Date as month, day, year | Sample start time | Chlorpyrifos oxygen analog, water, filtered, recoverable, micrograms per liter | *cis*-Propiconazole, water, filtered, recoverable, micrograms per liter | DCPA, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter | Disulfoton sulfone, water, filtered, recoverable, micrograms per liter |
|---|---|---|---|---|---|---|---|
| 345822086254001 | 1 | 4/27/2009 | 1300 | <0.05 | <0.006 | <0.006 | <0.01 |
| 345112086313401 | 2 | 4/27/2009 | 1630 | <0.05 | <0.006 | <0.006 | <0.01 |
| 344124086531401 | 3 | 6/11/2009 | 1645 | <0.05 | <0.006 | <0.006 | <0.01 |
| 344348086493401 | 4 | 4/28/2009 | 1615 | <0.05 | <0.006 | <0.006 | <0.01 |
| 344131087335201 | 5 | 4/28/2009 | 1330 | E0.06 | <0.006 | 0.015 | 0.02 |
| 312143085230301 | 6 | 6/10/2009 | 1155 | <0.05 | E0.006 | <0.006 | <0.01 |
| 311928085191101 | 7 | 6/10/2009 | 1500 | <0.05 | <0.006 | <0.006 | <0.01 |
| 311048085403201 | 8 | 6/11/2009 | 1355 | <0.05 | <0.006 | <0.006 | <0.01 |
| 310453085383001 | 9 | 6/11/2009 | 1010 | <0.05 | <0.006 | <0.006 | <0.01 |
| 310153085225901 | 10 | 6/12/2009 | 0920 | <0.05 | <0.006 | <0.006 | <0.01 |
| 303432087485501 | 11 | 6/16/2009 | 1305 | <0.05 | <0.006 | <0.006 | <0.01 |
| 303252087500801 | 12 | 6/16/2009 | 1445 | <0.05 | <0.006 | <0.006 | <0.01 |
| 303231087525801 | 13 | 6/17/2009 | 0930 | <0.05 | <0.006 | <0.006 | <0.01 |
| 302434087462601 | 14 | 6/17/2009 | 1230 | <0.05 | <0.006 | <0.006 | <0.01 |
| 302438087325801 | 15 | 6/17/2009 | 1555 | <0.05 | <0.006 | <0.006 | <0.01 |

**Table 4.** Results of U.S. Geological Survey National Water Quality Laboratory schedule 2033 pesticide analyses for samples collected from groundwater wells in areas of high-density row crop production in Alabama, 2009.—Continued

[USGS, U.S. Geological Survey; E, estimated; —, missing; <, less than]

| USGS station number | Map number (figs. 2–4) | Date as month, day, year | Sample start time | Metalaxyl, water, filtered, recoverable, micrograms per liter | Metolachlor, water, filtered, recoverable, micrograms per liter | Metribuzin, water, filtered, recoverable, micrograms per liter | Molinate, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter |
|---|---|---|---|---|---|---|---|
| 345822086254001 | 1 | 4/27/2009 | 1300 | E0.015 | 0.019 | <0.016 | <0.002 |
| 345112086313401 | 2 | 4/27/2009 | 1630 | <0.007 | <0.014 | <0.016 | <0.002 |
| 344124086531401 | 3 | 6/11/2009 | 1645 | <0.007 | 0.067 | <0.016 | <0.002 |
| 344348086493401 | 4 | 4/28/2009 | 1615 | <0.007 | E0.006 | <0.016 | <0.002 |
| 344131087335201 | 5 | 4/28/2009 | 1330 | <0.007 | 0.06 | <0.016 | 0.022 |
| 312143085230301 | 6 | 6/10/2009 | 1155 | <0.007 | E0.01 | <0.016 | <0.004 |
| 311928085191101 | 7 | 6/10/2009 | 1500 | <0.007 | <0.014 | <0.016 | <0.002 |
| 311048085403201 | 8 | 6/11/2009 | 1355 | <0.007 | <0.014 | <0.016 | <0.002 |
| 310453085383001 | 9 | 6/11/2009 | 1010 | <0.007 | E0.004 | <0.016 | <0.002 |
| 310153085225901 | 10 | 6/12/2009 | 0920 | <0.007 | <0.014 | <0.016 | <0.002 |
| 303432087485501 | 11 | 6/16/2009 | 1305 | <0.007 | 0.068 | <0.016 | <0.002 |
| 303252087500801 | 12 | 6/16/2009 | 1445 | <0.007 | <0.014 | <0.016 | <0.002 |
| 303231087525801 | 13 | 6/17/2009 | 0930 | <0.007 | <0.014 | <0.016 | <0.002 |
| 302434087462601 | 14 | 6/17/2009 | 1230 | <0.007 | <0.014 | <0.016 | <0.002 |
| 302438087325801 | 15 | 6/17/2009 | 1555 | 0.03 | 4.08 | 0.023 | <0.002 |

| USGS station number | Map number (figs. 2–4) | Date as month, day, year | Sample start time | Prometon, water, filtered, recoverable, micrograms per liter | Prometryn, water, filtered, recoverable, micrograms per liter | Simazine, water, filtered, recoverable, micrograms per liter | Tebuthiuron, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter |
|---|---|---|---|---|---|---|---|
| 345822086254001 | 1 | 4/27/2009 | 1300 | <0.01 | 0.01 | E0.005 | <0.02 |
| 345112086313401 | 2 | 4/27/2009 | 1630 | <0.01 | <0.006 | <0.01 | <0.02 |
| 344124086531401 | 3 | 6/11/2009 | 1645 | 0.02 | 0.007 | 0.013 | <0.02 |
| 344348086493401 | 4 | 4/28/2009 | 1615 | <0.01 | <0.006 | <0.01 | <0.02 |
| 344131087335201 | 5 | 4/28/2009 | 1330 | <0.01 | 0.027 | 0.05 | <0.02 |
| 312143085230301 | 6 | 6/10/2009 | 1155 | <0.01 | <0.006 | <0.01 | 0.12 |
| 311928085191101 | 7 | 6/10/2009 | 1500 | <0.01 | <0.006 | <0.01 | <0.02 |
| 311048085403201 | 8 | 6/11/2009 | 1355 | <0.01 | <0.006 | <0.01 | <0.02 |
| 310453085383001 | 9 | 6/11/2009 | 1010 | <0.01 | <0.006 | <0.01 | <0.02 |
| 310153085225901 | 10 | 6/12/2009 | 0920 | <0.01 | <0.006 | <0.01 | <0.02 |
| 303432087485501 | 11 | 6/16/2009 | 1305 | <0.01 | <0.006 | <0.01 | <0.02 |
| 303252087500801 | 12 | 6/16/2009 | 1445 | <0.01 | <0.006 | <0.01 | <0.02 |
| 303231087525801 | 13 | 6/17/2009 | 0930 | <0.01 | <0.006 | <0.01 | <0.02 |
| 302434087462601 | 14 | 6/17/2009 | 1230 | <0.01 | <0.006 | <0.01 | <0.02 |
| 302438087325801 | 15 | 6/17/2009 | 1555 | <0.01 | <0.006 | <0.01 | <0.02 |

**Table 4.** Results of U.S. Geological Survey National Water Quality Laboratory schedule 2033 pesticide analyses for samples collected from groundwater wells in areas of high-density row crop production in Alabama, 2009.—Continued

[USGS, U.S. Geological Survey; E, estimated; —, missing; <, less than]

| USGS station number | Map number (figs. 2–4) | Date as month, day, year | Sample start time | Terbuthylazine, water, filtered, recoverable, micrograms per liter | Thiobencarb, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter | *trans*-Propiconazole, water, filtered, recoverable, micrograms per liter |
|---|---|---|---|---|---|---|
| 345822086254001 | 1 | 4/27/2009 | 1300 | <0.01 | <0.016 | <0.02 |
| 345112086313401 | 2 | 4/27/2009 | 1630 | <0.01 | <0.016 | <0.02 |
| 344124086531401 | 3 | 6/11/2009 | 1645 | <0.01 | <0.016 | <0.02 |
| 344348086493401 | 4 | 4/28/2009 | 1615 | <0.01 | <0.016 | <0.02 |
| 344131087335201 | 5 | 4/28/2009 | 1330 | 0.02 | 0.029 | <0.02 |
| 312143085230301 | 6 | 6/10/2009 | 1155 | <0.01 | <0.016 | E0.01 |
| 311928085191101 | 7 | 6/10/2009 | 1500 | <0.01 | <0.016 | <0.02 |
| 311048085403201 | 8 | 6/11/2009 | 1355 | <0.01 | <0.016 | <0.02 |
| 310453085383001 | 9 | 6/11/2009 | 1010 | <0.01 | <0.016 | <0.02 |
| 310153085225901 | 10 | 6/12/2009 | 0920 | <0.01 | <0.016 | <0.02 |
| 303432087485501 | 11 | 6/16/2009 | 1305 | <0.01 | <0.016 | <0.02 |
| 303252087500801 | 12 | 6/16/2009 | 1445 | <0.01 | <0.016 | <0.02 |
| 303231087525801 | 13 | 6/17/2009 | 0930 | <0.01 | <0.016 | <0.02 |
| 302434087462601 | 14 | 6/17/2009 | 1230 | <0.01 | <0.016 | <0.02 |
| 302438087325801 | 15 | 6/17/2009 | 1555 | <0.01 | <0.016 | <0.02 |

**Table 5.** Results of U.S. Geological Survey National Water Quality Laboratory schedule 2060 pesticide analyses for samples collected from groundwater wells in areas of high-density row crop production in Alabama, 2009.

[USGS, U.S. Geological Survey; E, estimated; —, missing; <, less than]

| USGS station number | Map number (figs 2–4) | Date as month, day, year | Sample start time | 2-Chloro-4-isopropylamino-6-amino-s-triazine, water, filtered, recoverable, micrograms per liter | 2-Chloro-6-ethylamino-4-amino-s-triazine, water, filtered, recoverable, micrograms per liter | 2-Hydroxy-4-isopropylamino-6-ethylamino-s-triazine, water, filtered, recoverable, micrograms per liter | Aldicarb sulfone, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter |
|---|---|---|---|---|---|---|---|
| 345822086254001 | 1 | 6/11/2009 | 1300 | E0.04 | E0.01 | E0.007 | E0.01 |
| 345112086313401 | 2 | 6/11/2009 | 0915 | 0.1 | E0.01 | E0.006 | — |
| 344124086531401 | 3 | 6/11/2009 | 1645 | E0.213 | E0.05 | E0.02 | <0.08 |
| 344348086493401 | 4 | 6/10/2009 | 1500 | E0.02 | <0.06 | E0.014 | 0.13 |
| 344131087335201 | 5 | 6/12/2009 | 1110 | E0.04 | E0.02 | E0.008 | <0.08 |

| USGS station number | Map number (figs 2–4) | Date as month, day, year | Sample start time | Aldicarb sulfoxide, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter | Atrazine, water, filtered, recoverable, micrograms per liter | Diuron, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter | Fluometuron, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter |
|---|---|---|---|---|---|---|---|
| 345822086254001 | 1 | 6/11/2009 | 1300 | <0.06 | 0.111 | E0.02 | 0.32 |
| 345112086313401 | 2 | 6/11/2009 | 0915 | E0.006 | 0.107 | E0.02 | 0.23 |
| 344124086531401 | 3 | 6/11/2009 | 1645 | E0.002 | 0.25 | E0.04 | 0.28 |
| 344348086493401 | 4 | 6/10/2009 | 1500 | E0.021 | 0.352 | <0.04 | 0.5 |
| 344131087335201 | 5 | 6/12/2009 | 1110 | <0.06 | E0.012 | <0.04 | 0.28 |

| USGS station number | Map number (figs 2–4) | Date as month, day, year | Sample start time | Imidacloprid, water, filtered, recoverable, micrograms per liter | Metalaxyl, water, filtered, recoverable, micrograms per liter | Methomyl, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter | Norflurazon, water, filtered (0.7 micron glass fiber filter), recoverable, micrograms per liter |
|---|---|---|---|---|---|---|---|
| 345822086254001 | 1 | 6/11/2009 | 1300 | 0.066 | E0.01 | E0.009 | E0.03 |
| 345112086313401 | 2 | 6/11/2009 | 0915 | <0.06 | <0.04 | <0.12 | E0.02 |
| 344124086531401 | 3 | 6/11/2009 | 1645 | <0.06 | <0.04 | <0.12 | E0.02 |
| 344348086493401 | 4 | 6/10/2009 | 1500 | <0.06 | <0.04 | <0.12 | 0.82 |
| 344131087335201 | 5 | 6/12/2009 | 1110 | E0.024 | <0.04 | <0.12 | E0.04 |

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