Nitrate in Georgia's Ground Water

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Atlanta
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PROJECT REPORT 25

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ABSTRACT

As part of U. S. Environmental Protection Agency (EPA) grants funded under section 319-h of the federal Clean Water Act, potential pollution of ground water by nitrate in Georgia was evaluated by sampling 5,072 domestic drinking water wells in 146 of Georgia's 159 counties. Wells sampled are believed to be representative of ground water actually being consumed by rural residents of the state. Wells showing nitrate levels of 5.0 mg/l nitrate as N or greater were resampled and any sources of nitrogen pollution near the wellhead noted. In addition, streams in Barrow, Lumpkin, and Morgan counties, which are characterized by poultry and dairy operations, were sampled to assess base-flow contributions to surface water. The data collected demonstrate that human induced pollution of ground water by nitrate is not a significant problem in Georgia at this time. Individual wells with higher nitrate levels generally have sources, such as fertilized lawns, gardens, or fields, septic tank leach fields, or animal enclosures close to the wellhead. Improper well construction was also identified as a problem in some cases. Recommendations for future sampling and recommendations to home owners to protect their wells are made.

A statistical analysis of the significance of the well sampling results is provided in Appendix D.

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INTRODUCTION

Ground water is the source for an estimated 53 percent of all drinking water in the United States, with rural residents dependent upon ground water for 97 percent of their drinking water supply (Moody, 1991). This, along with the fact that Georgians use nearly one billion gallons of ground water per day (Figure 1, Fanning and others, 1992), makes apparent the need for ground-water quality monitoring. The Georgia Environmental Protection Division (EPD) has been sampling and testing the state's ground water for many years as part of its Ground-Water Management Plan for Georgia (EPD, 1991).

Potential pollution sources can be divided into two groups: point sources and non-point sources. Some examples of point sources of pollution include landfills, hazardous waste sites, underground storage tanks, and feedlots. Non-point pollution sources include agricultural use of fertilizer and pesticides on crops and leaching of animal wastes from pastures or enclosures. Increased turbidity of streams due to suspended sediment from soil erosion is also an important form of non-point pollution. While domestic and non-domestic septic systems are individually point sources, they are so widespread that they are typically considered non-point sources of pollution.

Nitrate from non-point agricultural sources has affected ground-water quality in several states (Madison and Brunett, 1984; Hallberg, 1989; Fedkiw, 1991; and Spalding and Exner, 1993). The federal Clean Water Act of 1986 required states to assess non-point water pollution sources and to develop appropriate management plans. To expedite completion of these plans, Section 319-h of the Act offered grant programs through the U. S. Environmental Protection Agency (EPA) to the states for non-point source ground-water protection activities (Danielson and Patte, 1991). Georgia has received such grants since 1990 to assist in protecting surface and ground-water from non-point pollution. Previously published data on nitrate in ground water does not indicate that nitrate is a significant problem in Georgia (Madison and Brunett, 1984). EPD, nevertheless, believed it prudent to utilize the ground-water portion of its Non-Point Source Grant for the federal fiscal years 1990 through 1994 to comprehensively evaluate potential nitrate pollution in the state's ground water by sampling domestic drinking water wells and base flow of some streams. Stuart and others (1995) prepared a report on the first part of EPD's nitrate study, noting that results from south Georgia indicated a general lack of human-induced nitrate pollution. Likewise, Robertson and others (1993) noted that nearby sources of pollution are present for the few wells in northern Georgia that tested high.

The most common sources of non-point nitrate pollution in Georgia are fertilizer application to crops, land application of waste from poultry and livestock operations,

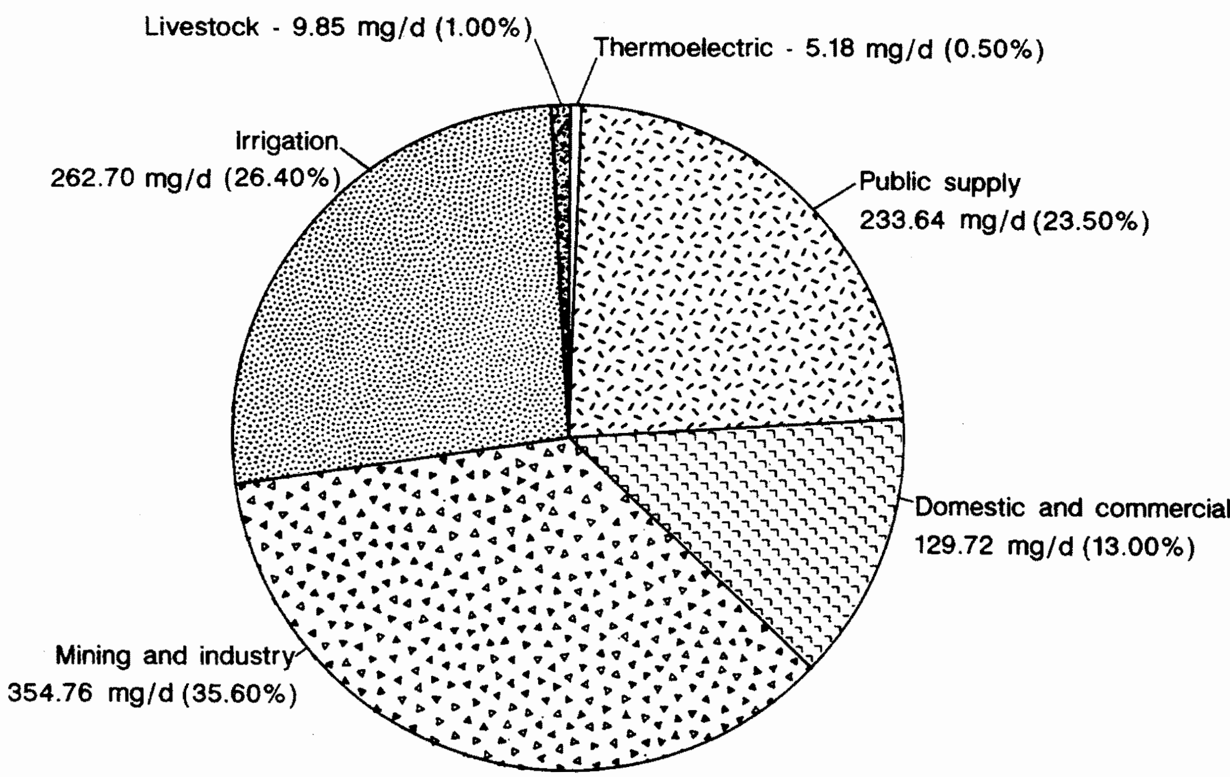

Figure 1. Ground-water use in Georgia for 1990 in millions of gallons per day (mg/d) (from Fanning, Doonan, and Montgomery, 1992).

livestock pasturing, and rural residential developments on septic systems. In Georgia, most row cropping takes place in the Coastal Plain Physiographic Province of southern Georgia, whereas livestock operations and residential developments on septic systems are more common in the Piedmont Physiographic Province of northern Georgia, outside of the Atlanta metropolitan area. Poultry operations are common in rural areas, particularly in the northern part of the state. Leaching of soil as a result of irrigation has been demonstrated to cause increased nitrate levels in ground water in arid western states (Spalding and Exner, 1993) and has been suggested to be a factor in non-point nitrate pollution in the irrigated areas of south Georgia (Hubbard and others, 1986). Human-related point source nitrate pollution may come from unlined landfills, fertilizer manufacturing and storage, land application of waste water and sewage sludge, feedlots, and livestock waste disposal facilities. Increased levels of natural nitrogen in the soil and ground water also may occur in wetland areas where large volumes of organic matter are decomposing. Background levels of natural nitrogen in ground water derive from a combination of soil nitrogen and atmospheric deposition.

While natural nitrate in ground water varies considerably from place to place, depending on local soils and geologic and climatic circumstances, it rarely exceeds the 10 mg/l nitrogen (N) health based Maximum Contaminant Limit (MCL) set by the EPA for drinking water (Fedkiw, 1991). EPD has incorporated the 10 mg/l (measured as N) MCL into its Rules for Safe Drinking Water and strictly enforces this limit for all public water supplies in the state. The EPD believes that human-induced pollution is responsible at any site which exceeds the MCL. Properly constructed wells in Georgia, without obvious sources of nitrate near the wellhead, typically have values ranging from not detected up to about 3 mg/l N. Likewise, authors of regional reviews of nitrate in ground water in the United States, such as Madison and Brunett (1984), Hallberg (1989), and Spalding and Exner (1993), state that ground water with 3 mg/l N or less cannot be considered unequivocally to have been influenced by human activity, whereas values above 3 mg/l are generally considered to represent an increase caused by human activity. For the purposes of this report, EPD places values in three categories: [1] non-detectable to 3 mg/l nitrate are considered background (i.e., cannot be demonstrated to result from human activities); [2] 3.1 to 9.9 mg/l N are considered to be the result of some kind of human activity, but do not represent a risk to human health; and [3] 10.0 mg/l N and higher exceed the MCL for drinking water and represent a health risk for pregnant women and human infants.

Nitrate in ground water as a result of agricultural practices is reported to be a significant problem in some parts of the United States (Madison and Brunett, 1984; Spalding and Exner, 1993). Nitrate problems are more widespread in the Great Plains (Nebraska through western Texas) and in some areas of California and Arizona, where semi-arid to arid climatic conditions and intense agriculture supported by irrigation are probably the reason. Alkaline or sandy arid soils require more fertilizer, and unused nitrate is more easily leached when under irrigation. The southeastern states have fewer problems with excess nitrate. Higher temperatures, abundant rainfall, and soils with relatively high organic content are thought to promote denitrification below the root zone (Spalding and Exner, 1993). According to Madison and Brunett (1984), eight of eleven states with less than one percent of wells tested exceeding 10 mg/l N are in the southeastern United States.

THE NITRATE CYCLE

In the terrestrial ecosystem, nitrogen is an important component of air and of all living things. It is recovered from dead organisms and from waste products through the action of decomposing bacteria and fungi. Transformer bacteria convert organic nitrogen to inorganic forms which can be absorbed and utilized by plants. The plants die or are consumed by animals, including humans, which in turn make waste and die, completing the cycle. The nitrogen cycle is one of the fundamental chemical transformations that makes life possible.

Generalized pathways for nitrogen compounds in soils are illustrated in Figure 2. The amount of nitrate that enters the ground water is controlled by a complex set of hydrological, chemical, and biological processes. Atmospheric ammonia and nitrate enters the soil with precipitation. Atmospheric nitrogen undergoes microbial fixation. Plant residues and human and animal wastes provide organic nitrogen, proteins, and ammonia which undergo decomposition and nitrification to produce nitrate in the soil. Nitrogen fixed by microbes is also released through decomposition to produce ammonium which undergoes nitrification to produce more nitrate. Inorganic fertilizers release ammonia which oxidizes to nitrite or nitrate.

Nitrate is soluble and mobile in soil. Plants absorb nitrate and ammonium to produce plant proteins. Some nitrate in the soil undergoes the process of denitrification and changes into nitrogen gas, which returns to the atmosphere. The remaining nitrate in the soil may leach to ground water. Where denitrification processes are active, however, little nitrate may remain to leach to ground water.

The concentration of nitrogen compounds varies widely in the soil, depending on environmental conditions. Maintaining appropriate levels of soluble nitrate in the soil during the growing season is vital for efficient agriculture. When nitrate reaches ground water, it remains in solution and moves with the ground water to wells and surface streams. Typically, little further denitrification takes place in the ground water. Leaching of nitrate into ground water is dependent on the effectiveness of denitrification processes below the root zone, precipitation (or irrigation), temperature, and soil type. Shallow drinking water wells downgradient of agricultural fields are, obviously, most at risk from nitrate leaching. Leaching from agricultural applications may be lessened by employing best management practices such as controlling the use of irrigation to minimize leach-through,

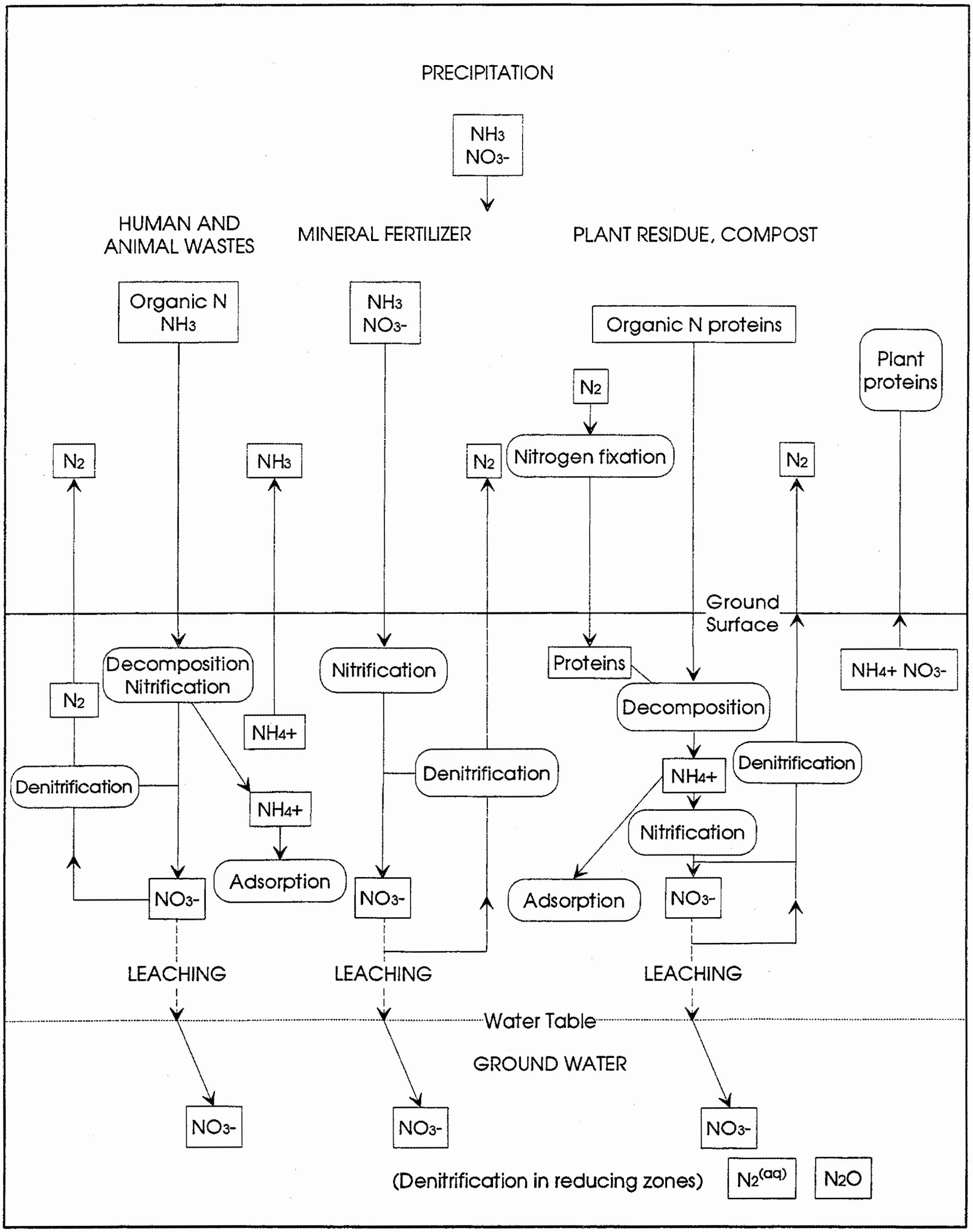

Figure 2. Pathways of nitrogen in soil and ground water. Chemical symbols: N, elemental nitrogen; N_2, nitrogen gas; N_2O, nitrous oxide; NO_2^-, nitrite; NO_3^-, nitrate; NH_4^+, ammonium; NH_3, ammonia; $N_2(aq)$, nitrogen gas dissolved in water. (Modified from Freeze and Cherry, 1979.)

rotating crops requiring high fertilization with those that require less, applying fertilizer only at recommended rates for crop and soil type and at appropriate times, and using fertilizers with nitrification inhibitors.

HEALTH RISKS

Ingesting water with high levels of nitrate may adversely affect health in humans and animals. It has long been recognized that methemoglobinemia (blue-baby syndrome) in human infants and young animals is strongly related to drinking nitrate-laden water. This threat led EPA to establish the MCL for drinking water in the United States at 10 mg/l N. Similarly, the European drinking water standard was set at 11.3 mg/l N. No health risk has been detected for human infants from drinking water containing less than 10 mg/l N.

In spite of the fact that the nitrate anion itself poses no health danger, methemoglobinemia occurs when ingested nitrate is converted to the nitrite ion (NO_2^-) in the mouth and stomach and is then absorbed from the gastro-intestinal tract into the blood (Follett and Walker, 1989). Nitrite in the blood results in the oxidation of hemoglobin to methemoglobin. Ferrous iron (Fe^{+2}) is oxidized to ferric iron (Fe^{+3}) to which nitrite bonds firmly, inhibiting transport of oxygen by the blood. Infants younger than 3 months of age are highly susceptible to gastric bacterial nitrate reduction because they have very little gastric acid production and low activity of the enzyme that reduces methemoglobin back to hemoglobin. Diarrhea, if present, lowers tolerance for nitrate in infants.

Nitrate can become toxic to ruminants, horses, and baby pigs when it is reduced to nitrate by bacteria in the digestive system. Nitrate toxicity is a problem with ruminant animals in which bacterial reduction of nitrate to nitrite occurs in the rumen during the first stage of digestion (Follett and Walker, 1989). Susceptibility varies between species, but it is generally recommended that nitrate levels in drinking water for animals not exceed 40 mg/l N (Fedkiw, 1991). Nonlethal doses of nitrate have been associated with multiple spontaneous abortions in cattle.

Nitrite produced in the body also reacts with secondary and tertiary amines to form nitrosamines. Nitrosamines are known to be carcinogenic in test animals and may represent another threat to human health (Mirvish, 1991).

High nitrate in surface water enhances the growth of algae and aquatic plants. Therefore, the most significant environmental effect of high nitrate is eutrophication of streams, lakes, and estuaries. Excess plant growth due to the stimulation of nitrogen in water causes depletion of dissolved oxygen and hypoxia of bottom waters. Mass mortalities of finfish and shellfish have been caused by nutrient enrichment. With the removal of phosphorus from detergents, once the most important cause of eutrophication, nitrate from fertilizer and other sources may have become the most significant contributor to environmental degradation of surface waters (Fedkiw, 1991).

THE GEORGIA NITRATE SURVEY

The Georgia Geologic Survey Branch of EPD sampled 5,072 domestic drinking water wells for nitrate (Figure 3), beginning in the summer of 1990 and ending in the summer of 1995. Wells were sampled in 146 of Georgia's 159 counties. Areas not sampled included the intensely urbanized core of the Atlanta metropolitan area because well usage is rare. Counties along the Atlantic coast and in southeastern Georgia, where there is little agriculture and where domestic drinking water wells are typically drilled to the deeply confined Floridan aquifer, were not sampled.

The number of wells tested per county ranges from a low of 5 to a high of 69 (Figure 3). Every attempt to equally distribute sample wells over a county was made, but limiting factors included the availability of drinking water from a county-wide distribution system, residential patterns, and the ease with which permission to sample wells was obtained. The domestic drinking water wells selected were sampled with the permission of the user. Preference was given to shallow bored wells where present, but most of those sampled were drilled wells.

The aquifer typically used for rural domestic drinking water varies throughout the state. EPD considers all drinking water aquifers north of the Fall Line (Figure 3) to be unconfined. Domestic wells in the northern or upper part of the Coastal Plain are also generally in unconfined aquifers as they are in southwestern Georgia. In southeastern Georgia, however, domestic wells are commonly drilled to the deeply confined Floridan aquifer in order to obtain a suitable quality and quantity of water. EPD believes that its selection of sample wells resulted in a significant test of the quality of ground water actually being consumed by rural residents in Georgia, even though EPD recognizes that water quality in the surface aquifer was not completely tested in the southeastern part of the state. Nitrate data from wells sampled are summarized by county in Appendix A.

All wells were sampled by a standardized methodology and, except for a few "rope and bucket" wells, utilized the electric well pumps installed by the owner. Most wells were sampled from a tap at the pressure tank or at the outside tap nearest the well. None of the wells had treatment systems attached. Most wells in south Georgia were sampled by students from Georgia Southern University (Stuart and others, 1995). The remainder in south Georgia and the rest of the state were sampled by EPD associates. Sampling began in the summer of 1990 and continued through the summer of 1995. Samples which showed nitrate values of 5 mg/l N during the initial survey were resampled and the area around the well examined for possible sources of nitrate pollution. High nitrate wells tested during the spring and summer of 1995 were not retested due to an insufficient amount of interim time having passed. These wells sites were, however, examined for possible pollution sources.

Permission to sample wells was initially obtained by "knocking on doors". As this procedure was relatively inefficient, EPD published a description of the Nitrate Survey

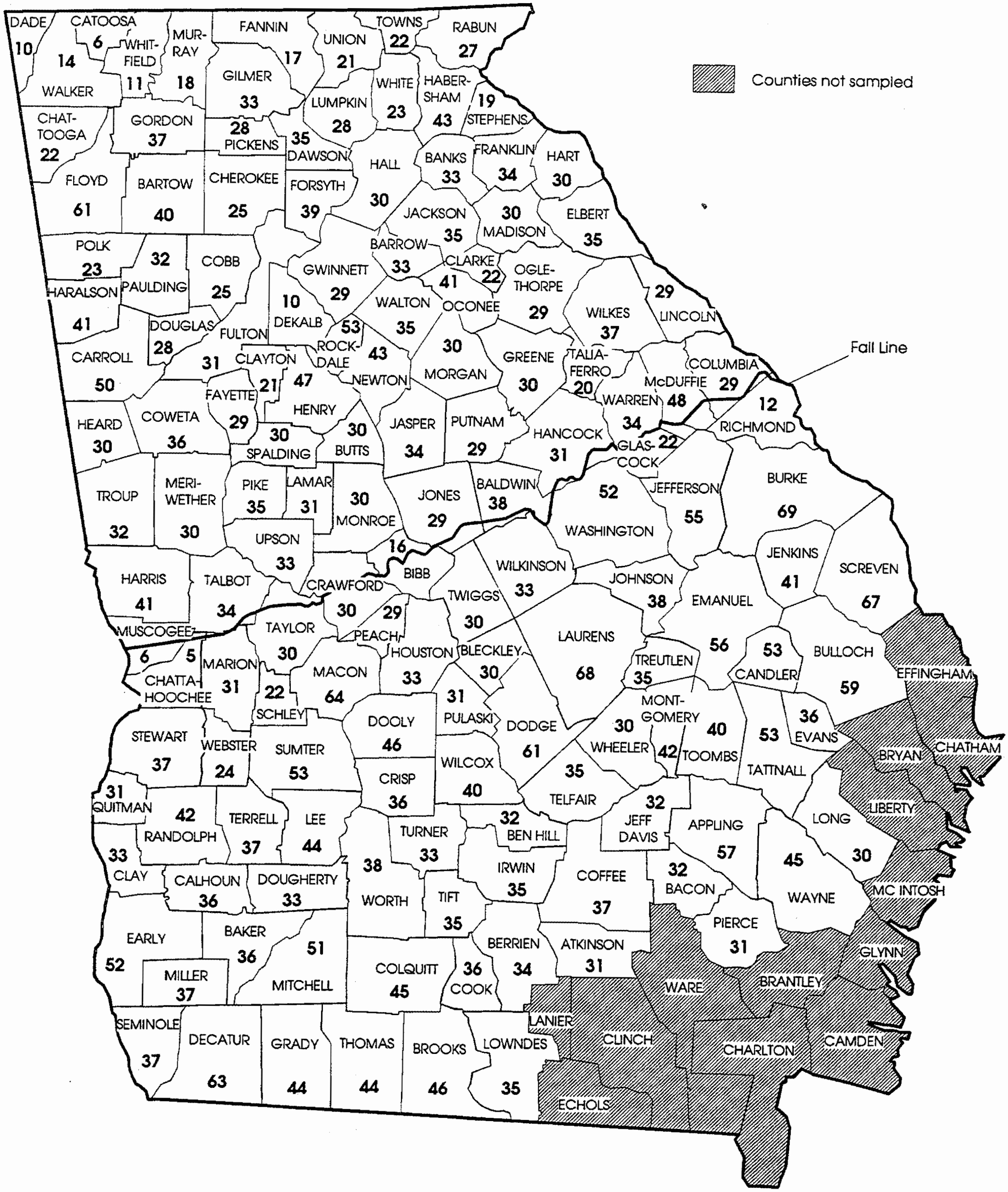

Figure 3. Number of wells tested per county.

in the January 22, 1992, issue of the Georgia Department of Agriculture's Farmers and Consumers Market Bulletin with a request that well owners interested in participating in the survey contact Georgia EPD. Letters also were sent to University of Georgia Cooperative Extension Agents in north Georgia counties with a copy of the article, description of the survey, and a request to forward these to local newspapers. This resulted in articles about the nitrate study being published in a number of local newspapers. This approach resulted in an abundance of responses from well owners interested in having EPD sample their wells.

In addition to sampling more than 5,000 domestic water wells, EPD sampled surface water in counties in northern Georgia which have the highest production of poultry (Barrow and Lumpkin) and milk (Morgan). The surface streams were sampled during low flow stages in the fall of 1994.

All nitrate sampling was funded by the U. S. EPA through the Non-Point Source Management Grant (319-h) for federal fiscal years 1990, 1991, 1992, 1993, and 1994. The preparation of this report was, in part, funded by the same grant for federal fiscal years 1993 and 1994.

Sampling Procedures

Students from Georgia Southern University employed the following procedure in their sampling (Stuart and others, 1995). Once permission from the owner or resident to sample the well was obtained, a manifold and hose system designed by EPD was attached to the outside spigot on or nearest to the pressure tank of the well. Water was allowed to flow through the manifold which consisted of a PVC pipe with holes to hold the probes of pH, specific conductivity, temperature, and dissolved oxygen meters. Meters were read every two minutes for a maximum of 18 minutes, at which time readings typically had stabilized. This indicated that the standing water in the well and pressure tank had been evacuated and fresh formation water, representative of the aquifer, had reached the manifold. Samples of the well water were then taken and analyzed on site for nitrate and other constituents utilizing Hach Company test kits.

The remainder of the wells in the study were sampled by EPD associates who used a similar manifold, but recorded pH, specific conductivity, and temperature every five minutes for a maximum of 30 minutes. EPD associates used a Hach One ISE meter backed up by Hach's low-range nitrate test kit (model 14161) (Robertson and others, 1993). Survey participants were given a copy of the results of the field test before the samplers left the site.

Each well was given a unique well identification number and plotted on the appropriate USGS 1:24,000 scale topographic quadrangle map. The latitude and longitude of each well was measured from the topographic map. The locational data were used to generate maps showing data points and values through use of EPD's Geographic Information System (GIS). The accuracy of the locations in the GIS database was compared to the original quadrangle maps and ascertained to be within two seconds of arc (about 200 feet). All field data were entered on paper forms and later entered into a GIS computer database.

Quality Control/Quality Assurance

The Hach One ISE (ion-selective electrode) meters were calibrated an average of once per month utilizing the two-standard calibration method as called for in the meter's manual. Intermittent checks on meter accuracy were performed using known nitrate standards to ensure accurate operation. Samples were taken from all EPD-tested wells showing greater than 5 mg/l N and delivered to the Division's analytical laboratory. In addition, six to eight samples per month with known nitrate values were submitted to the EPD laboratory for analysis along with field samples. High nitrate readings taken with the Hach One ISE meter were verified on site by use of the Hach High-Nitrate Test Cube (model 14037).

High Nitrate Wells

Wells which showed 5 mg/l N or above in the initial survey were later resampled. Field procedures and quality assurance methodologies during resampling were the same as those described previously. If the resampling showed that the well continued to have high nitrate levels, nearby wells were also sampled, if possible, to establish the extent of nitrate pollution. An assessment of well construction and land use practices was made at each site in order to identify the cause of the nitrate pollution. Of the 240 wells with 5 mg/l N or above in the initial survey, thirty were unavailable for retesting (well no longer in use, home unoccupied, or owner refused to give access). Seventy-four percent of the 210 wells sampled tested lower than the first test, the remaining 26 percent tested higher (Appendix B).

Low Flow Sampling

The final phase of the nitrate survey involved the base flow (or low flow) sampling of streams in three counties to measure the potential regional impacts of large scale poultry raising operations (Barrow and Lumpkin counties, Figures 4 and 5) and large dairy operations (Morgan County, Figure 6). These counties were chosen based upon livestock and poultry production figures from the 1993 Georgia County Guide published by the Cooperative Extension Service of the University of Georgia. A total of 347 stream samples were taken: 124 in Barrow County, 118 in Lumpkin, and 105 in Morgan (Appendix C).

Sampling was undertaken during a low stream flow period in September and October, 1994. During low flow periods, streams are comprised primarily of base flow derived from the water table aquifer. Water samples collected from streams during low flow periods are reasonably representative of the quality of ground water discharging from the water table aquifer. Rainfall, however, was much higher than average during 1994 (Figure 7). This being the case, EPD decided to begin sampling only after a period of at least two weeks with little or no rainfall. Appropriate conditions developed during a period of low rainfall from August 24 through September 18, 1994. Sampling began on September 14 and ended on October 7, 1994. Sampling was suspended for a day following short periods of precipitation during this time interval. Samples were taken with a clean container from flowing water in the streams and measured on site for nitrate using the Hach One ISE meter. The meter was calibrated as described earlier. Random samples were also transported to the Cooperative Extension Service laboratory in Athens for confirmation analysis.

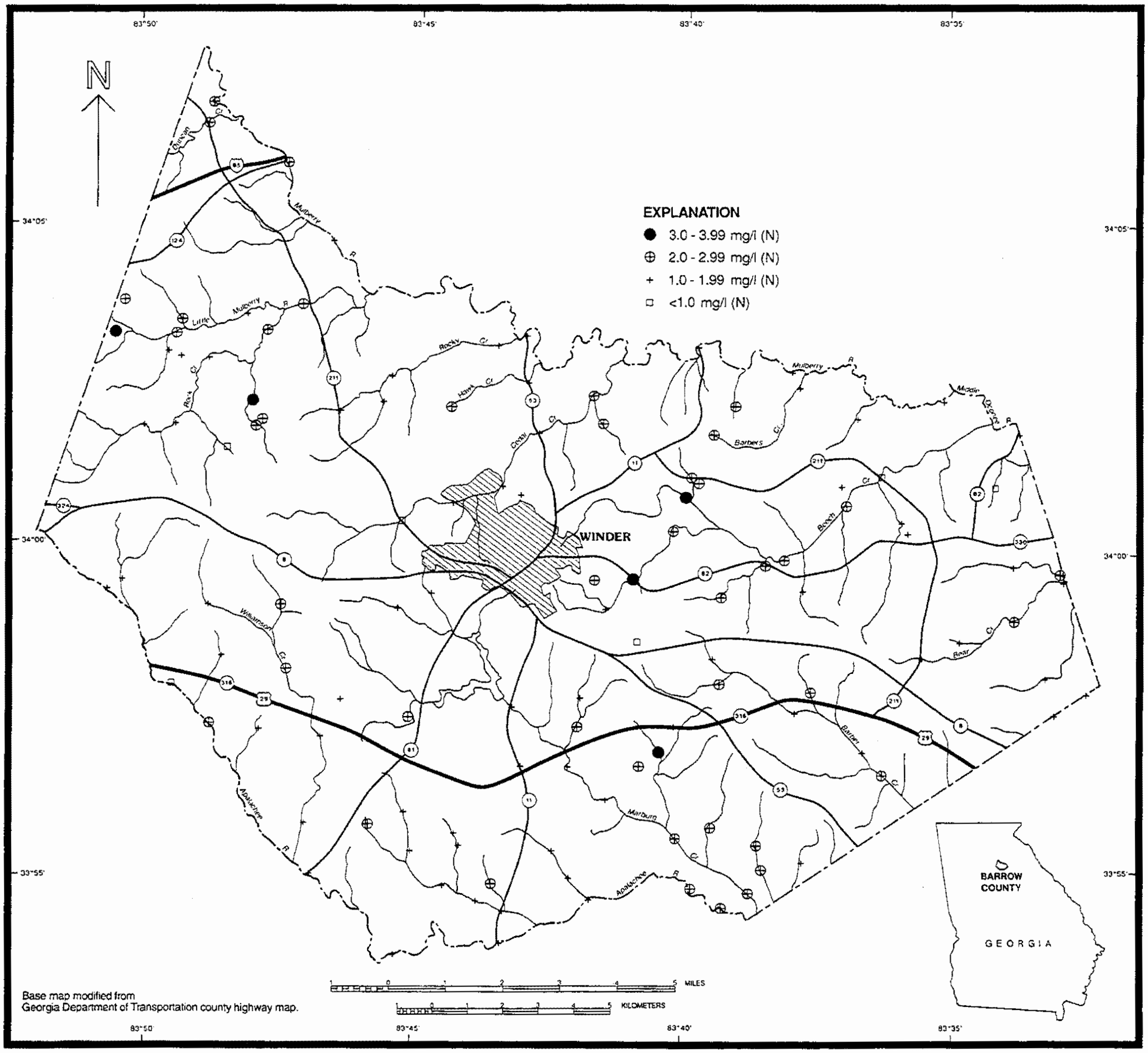

Figure 4. Surface water nitrate (N) concentrations in Barrow County.

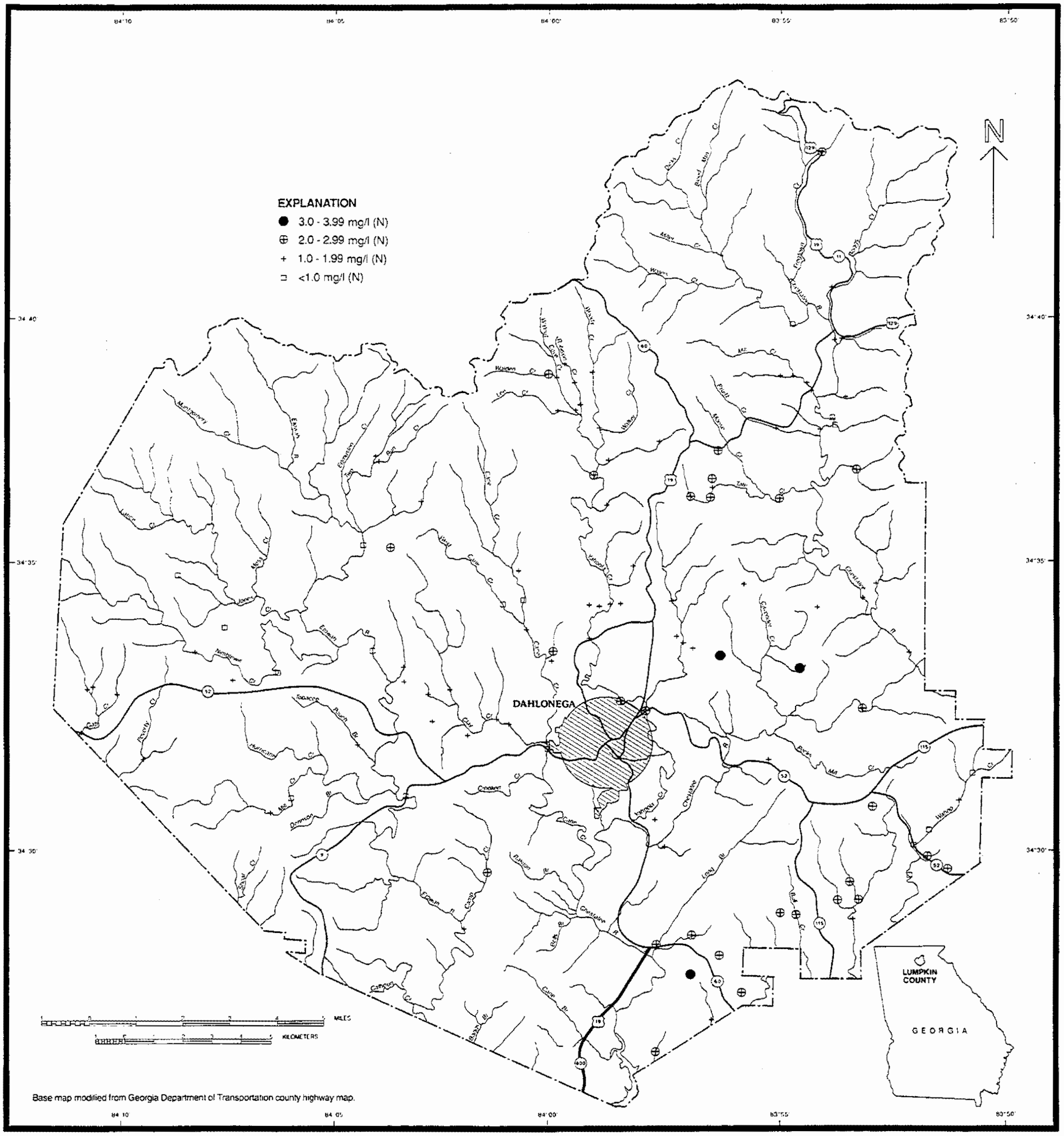

Figure 5. Surface water nitrate (N) concentrations in Lumpkin County.

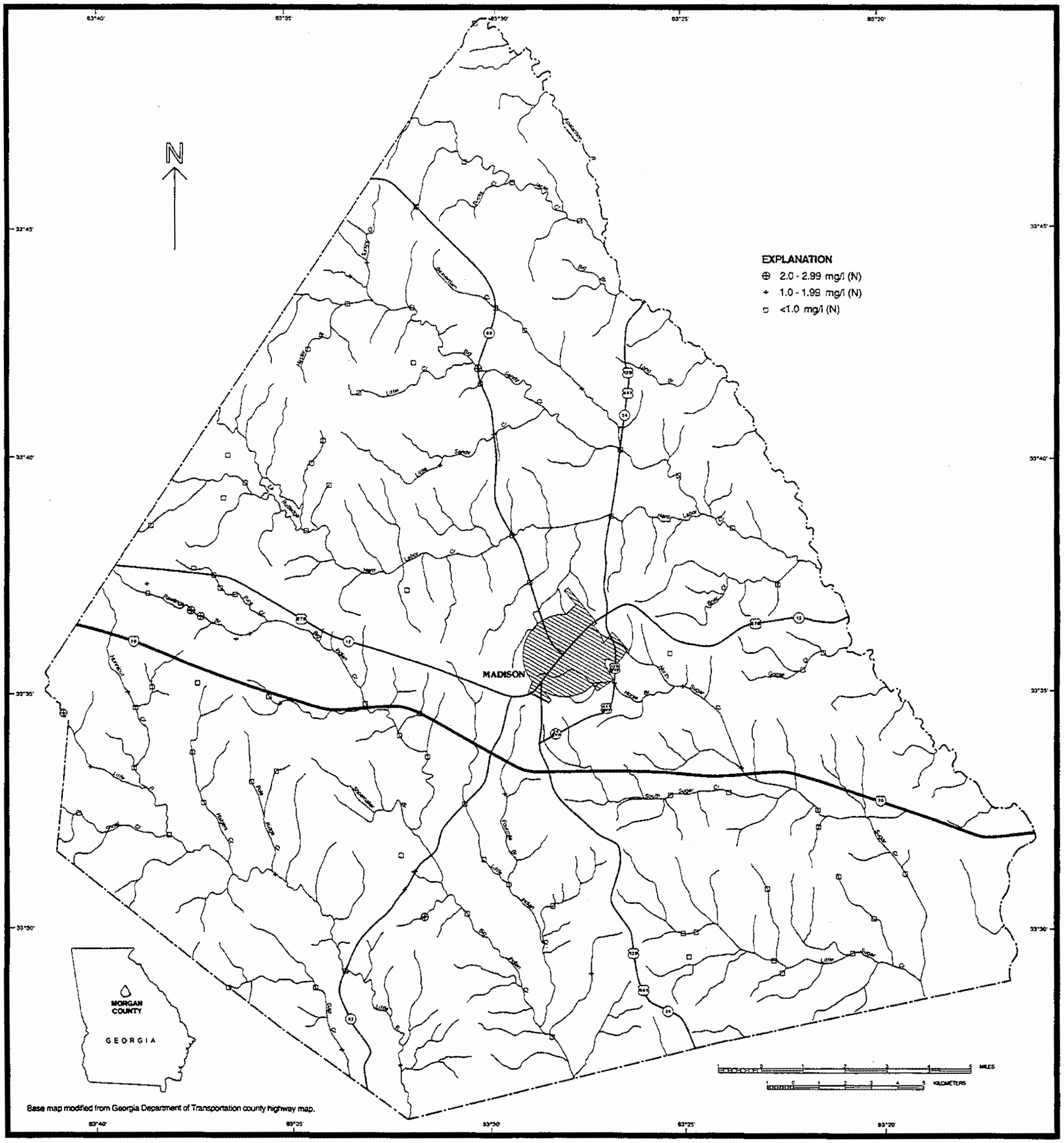

Figure 6. Surface water nitrate (N) concentrations in Morgan County.

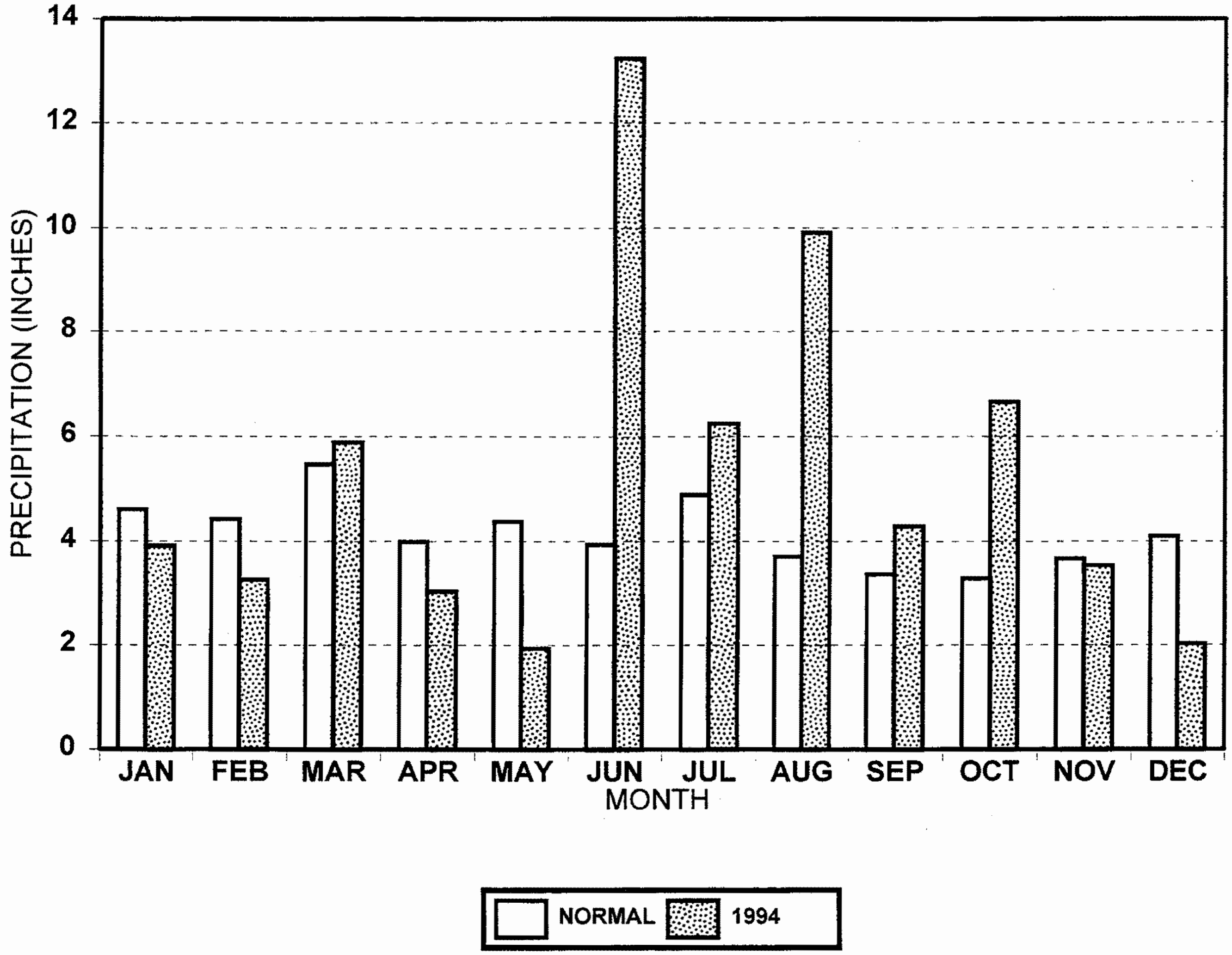

Figure 7. Comparison of precipitation at the Athens Weather Station: normal vs. 1994.
(Data from the National Weather Service, Southeast Agricultural Weather Service, Auburn, Alabama.)

RESULTS

The mean nitrate level in the domestic drinking water wells sampled during the Nitrate Survey is 0.99 mg/l N (standard deviation = 2.22). There is some variation in nitrate levels between counties, with those in the lower Coastal Plain (Appling, Pierce, Tattnall, and Toombs) having slightly higher mean levels. This may be due to higher natural nitrate levels in ground water of the lower Coastal Plain. Other counties, such as Hancock, have single wells with high nitrate values, which skew the mean value for the county as a whole. However, the highest mean nitrate level in any county was 2.7 mg/l. Approximately 73 percent of wells sampled contained less than 1 mg/l N. Thus, based on the presumption that values less than 3.1 mg/l N are indicative of background levels, these data strongly indicate that the ground water in no county sampled has been adversely affected by human-induced nitrate pollution.

Table 1 compares nitrate values from EPD's nitrate survey to those reported by Madison and Brunett (1984). Data from EPD's Survey (collected from 1990 to 1994) appear to indicate slightly higher nitrate levels than those reported by Madison and Brunett. The data they reported were collected over the 25 years previous to 1984 and are fewer in number.

Table 1. Nitrate values in Georgia: 1984 and 1994.

		% in Indicated Range of Values		
Year	# Sampled	0-3.0	3.1-9.9	≥10.0
1984	1,137	95.20	4.30	0.50
1994	5,072	92.47	6.31	1.22

When reviewed on an individual basis, wells containing 3.1 mg/l N or above are scattered across the state and no regional patterns of high nitrate pollution were found (Plate 1). Wells with higher nitrate values generally had sources in their immediate recharge areas. For example, one well had a nitrate concentration of 40 mg/l N. The sources were a nearby swine enclosure and residential sanitary waste deposited directly onto the ground surface near the well.

Wells originally having 5 mg/l N or greater in the initial survey were resampled and potential sources of nitrate near the wellhead were noted. An evaluation of potential sources of nitrate for resampled wells indicates that many high nitrate wells had a garden, lawn, or agricultural field near the wellhead to which fertilizer had been recently applied (Figure 8). Septic systems and animal waste constituted another significant potential source of nitrate. Improper construction of the well was a factor in only about 6 percent of the higher nitrate wells. Wells without grout (grouting is a legal requirement in Georgia) are particularly susceptible to having surface water, laden with nitrate, flow down the well bore to pollute the ground water. Obvious nearby sources of potential nitrate contamination could not be found for 15 percent of the higher nitrate wells.

The mean nitrate levels in ground water were calculated for wells located in areas of higher, average, or lower susceptibility to ground-water pollution as shown in Hydrologic Atlas 20 (Trent, 1992) utilizing EPD's GIS. These values are shown in Table 2. These data do not appear to indicate any significant variation between wells located in areas of different susceptibility to ground-water pollution.

Table 2: Mean Nitrate Values in Georgia Wells by Pollution Susceptibility Areas

P.S.A.	Frequency	Mean (mg/l)	S.D. (mg/l)
Higher	1,201	1.12	2.10
Average	1,873	0.89	2.33
Lower	1,963	1.00	2.19
Unclassified	35	---	---

Sampling of streams at low flow stages in three counties with the highest poultry production or dairy livestock production failed to show any significant impact from such agricultural activities on nitrate levels (Figures 4, 5, and 6; Appendix C). The highest values were 3.5 mg/l N and the mean was 1.47 mg/l N (standard deviation = 0.694). The mean values of nitrate for the surface water sampled was slightly higher than for ground water, but the nitrate level is generally below the level of nitrate which can be assumed to be associated with human activity.

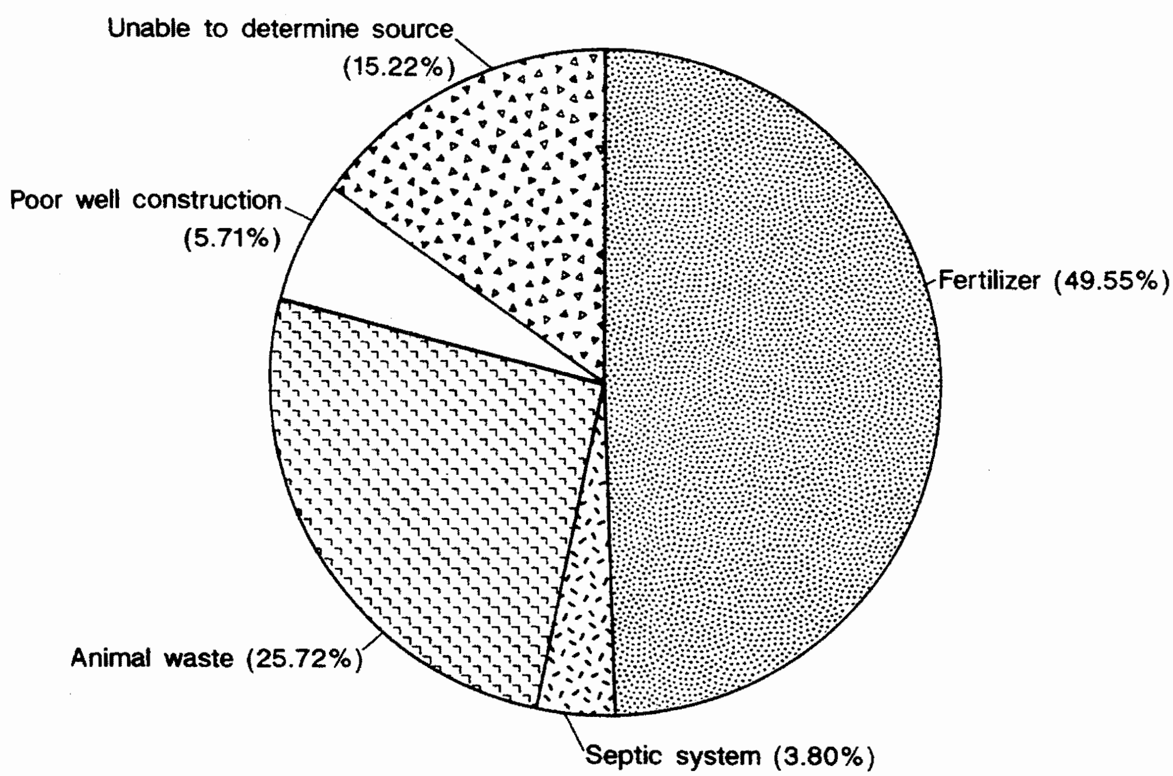

Figure 8. Sources of nitrate pollution in the 210 retested wells with 5 mg/l nitrate or above.

CONCLUSIONS AND RECOMMENDATIONS

EPD believes that the data collected during this survey of nitrate in aquifers being used as a drinking water source by rural residents demonstrates that nitrate pollution from human sources is not a significant problem in Georgia at this time. Individual wells, however, are susceptible to pollution from excess nitrate if improperly constructed or if the user maintains a nitrate source near a surficial aquifer well. These conclusions are mirrored in the earlier reports by Stuart and others (1995) and Robertson and others (1993).

It is recommended that EPD continue its present level of ground-water quality monitoring and periodically (10 year intervals) repeat the type of state-wide nitrate survey of domestic drinking water wells described in this report. Also, EPD should work with the University of Georgia Cooperative Extension Service to publicize the results of this study along with recommendations to well users. Specific recommendations should include the proper maintenance of wells and the replacement of any well not constructed correctly. Also, fertilizers should not be applied within 250 feet of a well that has elevated levels of nitrate. Any well showing high nitrate levels that is down gradient of a septic tank leach field or animal enclosure should be abandoned, properly plugged, and a new, safer well location found.

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Appendix A

Sample Data per County

APPENDIX A: SAMPLE DATA PER COUNTY

COUNTY	TOTAL SAMPLED	0-3.0 mg/l (N)	3.01-9.99 mg/l (N)	10.0 mg/l (N) & ABOVE	MINIMUM VALUE	MAXIMUM VALUE
APPLING	57	41	11	5	0	11
ATKINSON	31	30	1		0	5
BACON	32	32			0	2.6
BAKER	36	34	2		0	7.9
BALDWIN	38	38			0.1	2.9
BANKS	33	31	1	1	0.1	10.5
BARROW	33	30	3		0	3.2
BARTOW	40	38	2		0.1	6
BEN HILL	32	28	2	2	0	19
BERRIEN	34	31	3		0	8.4
BIBB	16	15	1		0.2	6.17
BLECKLEY	30	27	2	1	0	11
BROOKS	46	45	1		0	4
BULLOCH	59	55	3	1	0	11.6
BURKE	69	66	3		0	7.4
BUTTS	30	28	2		0	3.9
CALHOUN	36	33	3		0	8.5
CANDLER	53	46	5	2	0	16.7
CARROLL	50	49	1		0.1	3.2
CATOOSA	6	6			0.1	1.1
CHATTAHOOCHEE	5	5			0.02	0.6
CHATTOOGA	22	22			0.1	2.5
CHEROKEE	25	22	1	2	0.1	11
CLARKE	22	21	1		0.1	3.8
CLAY	33	30	3		0	8
CLAYTON	21	17	4		0.1	5
COBB	25	22	2	1	0.1	10
COFFEE	37	31	3	3	0	14
COLQUITT	45	41	4		0	9.2
COLUMBIA	29	26	3		0.1	4.6
COOK	36	35		1	0	3.5
COWETA	36	32	3	1	0.1	10.5
CRAWFORD	30	30			0.03	1.8
CRISP	36	32	1	3	0	13
DADE	10	10			0.1	0.1
DAWSON	35	33	2		0	5
DECATUR	63	56	7		0	8.2
DEKALB	10	10			0.1	3
DODGE	61	61			0	2
DOOLY	46	44	2		0	5.7
DOUGHERTY	33	33			0	1.7
DOUGLAS	28	28			0	2
EARLY	52	51	1		0	9

APPENDIX A: SAMPLE DATA PER COUNTY

COUNTY	TOTAL SAMPLED	0-3.0 mg/l (N)	3.01-9.99 mg/l (N)	10.0 mg/l (N) & ABOVE	MINIMUM VALUE	MAXIMUM VALUE
ELBERT	35	32	3		0.1	3.5
EMANUEL	56	56			0	2
EVANS	36	27	7	2	0	11.1
FANNIN	17	17			0	0.8
FAYETTE	29	25	4		0.1	6
FLOYD	61	59	2		0.1	7.6
FORSYTH	39	34	5		0.1	9
FRANKLIN	34	31	2	1	0.1	11.1
FULTON	31	28	1	2	0.1	10.5
GILMER	33	33			0.1	0.4
GLASCOCK	22	21		1	0.02	11.6
GORDON	37	36	1		0	4
GRADY	44	41	3		0	5.9
GREENE	30	27	3		0.1	5.8
GWINNETT	29	28	1		0.1	6
HABERSHAM	43	42	1		0.1	7
HALL	30	29	1		0	8.4
HANCOCK	31	29	1	1	0.1	58
HARALSON	41	41			0.1	2.8
HARRIS	41	40	1		0.1	4.8
HART	30	25	4	1	0.1	16
HEARD	30	29	1		0.1	4
HENRY	47	43	4		0.1	5.1
HOUSTON	33	33			0	2
IRWIN	35	32	2	1	0	28.6
JACKSON	35	33	2		0	9.1
JASPER	34	32	2		0.1	6
JEFF DAVIS	32	30	2		0	6
JEFFERSON	55	50	5		0	9.2
JENKINS	41	39	2		0	9
JOHNSON	38	37		1	0	11
JONES	29	28	1		0	9
LAMAR	31	28	3		0.1	3.8
LAURENS	68	65	3		0	9
LEE	44	40	4		0	6.5
LINCOLN	29	28	1		0.1	5
LONG	30	28	2		0	7
LOWNDES	35	35			0	1.3
LUMPKIN	28	28			0	0.4
MACON	64	48	13	3	0	17.4
MADISON	30	26	3	1	0.1	11.5
MARION	31	31			0.02	2.3
MCDUFFIE	48	44	4		0.1	9.5

APPENDIX A: SAMPLE DATA PER COUNTY

COUNTY	TOTAL SAMPLED	0-3.0 mg/l (N)	3.01-9.99 mg/l (N)	10.0 mg/l (N) & ABOVE	MINIMUM VALUE	MAXIMUM VALUE
MERIWETHER	30	28	2		0	5
MILLER	37	33	4		0	8.9
MITCHELL	51	49	2		0	8.3
MONROE	30	27	3		0	5.8
MONTGOMERY	42	36	4	2	0	10
MORGAN	30	26	3	1	0.1	32
MURRAY	18	18			0.1	2
MUSCOGEE	6	6			0.02	0.74
NEWTON	43	41	1	1	0.1	12
OCONEE	41	35	6		0.2	7
OGLETHORPE	29	27	2		0.1	5.1
PAULDING	32	26	5	1	0.1	11
PEACH	29	29			0	2.5
PICKENS	28	25	3		0.1	6
PIERCE	31	23	6	2	0	11
PIKE	35	35			0.1	3
POLK	23	19	3	1	0.1	11
PULASKI	31	31			0	2
PUTNAM	29	29			0.1	3
QUITMAN	31	30	1		0	9.4
RABUN	27	27			0.1	2.1
RANDOLPH	42	37	5		0	8.6
RICHMOND	12	12			0.4	2.6
ROCKDALE	53	50	3		0.1	4.8
SCHLEY	22	21	1		0.3	5.7
SCREVEN	67	65	2		0	5
SEMINOLE	37	33	4		0	6.4
SPALDING	30	28	2		0.1	5
STEPHENS	19	18		1	0.2	21
STEWART	37	30	5	2	0	11
SUMTER	53	49	4		0	9.8
TALBOT	34	33	1		0.1	5
TALIAFERRO	20	18	2		0.1	8.4
TATTNALL	53	37	16		0	9.2
TAYLOR	30	28	2		0.5	6.0
TELFAIR	35	31	2	2	0	30.8
TERRELL	37	34	3		0	5
THOMAS	44	36	6	2	0	11
TIFT	35	33	2		0	6.8
TOOMBS	40	31	6	3	0	11
TOWNS	22	22			0.1	0.9
TREUTLEN	35	33	1	1	0	10
TROUP	32	29	3		0.1	4.6

APPENDIX A: SAMPLE DATA PER COUNTY

COUNTY	TOTAL SAMPLED	0-3.0 mg/l (N)	3.01-9.99 mg/l (N)	10.0 mg/l (N) & ABOVE	MINIMUM VALUE	MAXIMUM VALUE
TURNER	33	30	2	1	0	11
TWIGGS	30	29	1		0.1	6.3
UNION	21	21			0	0.2
UPSON	33	32	1		0.1	9.5
WALKER	14	14			0.1	2
WALTON	35	31	3	1	0	13
WARREN	34	32	2		0.1	6
WASHINGTON	52	52			0	3
WAYNE	45	39	6		0	7
WEBSTER	24	22	2		0	6.8
WHEELER	30	26	3	1	0	10
WHITE	23	23			0	2.9
WHITFIELD	11	11			0	1.1
WILCOX	40	39	1		0	4
WILKES	37	30	7		0.1	5.3
WILKINSON	33	31		2	0.1	18.4
WORTH	38	37		1	0	11
TOTAL	5072	4690	320	62		

Appendix B

Resampled Well Data

APPENDIX B: RESAMPLED WELL DATA

COUNTY	WELL I.D.	QUADRANGLE	LATITUDE	LONGITUDE	TEST DATE	ORIGINAL NITRATE (N) VALUE	RE-TEST DATE	RE-TEST NITRATE (N) VALUE	NITRATE POLLUTION SOURCE/COMMENTS
Appling	CD-11	Alma NW	314019	822459	06/29/91	>10.0	12/22/92	20.5	Fertilizer; poor well construction
Appling	CD-18	Alma NE	313859	822012	06/30/91	5.3	08/05/93	4.4	Fertilizer from cultivated field across road
Appling	CD-93	Altamaha SE	314815	820625	07/06/91	7.3	10/26/93	4.1	Possible animal waste from up gradient pastures
Appling	CN-103	Surrency	313739	820952	07/06/91	5.0	10/25/93	<0.2	Possible fertilizer from up gradient field
Appling	CN-108	Grays Landing	315315	822500	07/07/91	6.86			New well - old well no longer in use
Appling	CR-280	Pine Grove	314716	822241	07/07/91	9.9	12/22/93	1.25	Could not determine source
Appling	D-97	Hazlehurst South	314959	823011	07/06/91	8.0	10/25/93	0.88	Could not determine source
Appling	N-102	K'ville	313336	820911	07/06/91	9.0			Well no longer in use
Appling	N-105	Altamaha	315245	821139	07/06/91	9.9	10/26/93	0.52	Possible fertilizer from up gradient cultivated fields
Appling	N-291	Altamaha SW	314524	821404	06/29/91	>10.0	12/23/92	8.3	Fertilizer from up gradient cultivated fields
Appling	N-294	Surrency	314031	821339	06/29/91	>10.0	01/14/93	6.5	Fertilizer from up gradient cultivated fields
Appling	N-296	Altamaha SW	314827	820828	06/29/91	5.0	08/05/93	4.5	Animal waste from pasture; poor well construction
Appling	N-299	K'ville	313527	821155	06/30/91	5.0	10/25/93	0.7	Possible fertilizer from up gradient cultivated fields
Appling	N-316	Baxley	315206	822008	07/07/91	7.0	08/11/93	2.8	Poor well construction
Atkinson	003-019	Kirkland	311952	825705	08/25/92	5.0	08/17/93	30.0	Fertilizer from up gradient corn and millet fields
Baker	007-002	Newton	312113	842139	04/15/91	6.0	08/10/93	<0.1	Waste from up gradient poultry enclosures
Baker	007-003	Newton	312221	842133	04/15/91	7.9	08/10/93	4.2	Fertilizer from up gradient (irrigated) peanut fields
Banks	011-004	Maysville	342001	833125	11/03/92	10.5	10/26/93	0.1	Animal waste from up gradient chicken houses
Bartow	015-032	Adairsville	342046	845613	10/28/92	6.0	09/28/93	0.5	Poor well construction
Ben Hill	DA-2	Osierfield	314115	830027	06/08/91	10.0	12/28/92	16.5	Possible up gradient fertilizer or animal waste
Ben Hill	N-235	Fitzgerald East	314205	830804	06/09/91	>10.0	01/15/93	9.0	Fertilizer from up gradient fields; poor well construction
Berrien	019-001	Lenox	312111	832506	09/03/91	8.37	08/16/93	0.5	Poor well construction
Berrien	019-029	Alapaha	312315	831110	07/27/92	7.5	08/16/93	2.3	Could not determine source
Bleckley	BJ-44	Danville East	323113	831256	03/24/91	5.0	12/28/93	1.5	Possible fertilizer from up gradient fields
Bleckley	JCH-22	Westlake	322430	832308	03/24/91	>10.0	12/02/92	124.0	Septic waste drainage from bathroom into yard
Bulloch	AN-9	Portal	323709	815550	09/14/90	8.8	02/16/94	3.3	Poultry enclosures surrounding well
Bulloch	MI-015	Denmark	321857	814024	01/17/91	11.6	02/15/94	15.4	Fertilizer from up gradient cultivated fields
Bulloch	031-003	Leefield	322602	813654	05/14/91	7.67			Well no longer in use - on city water
Burke	CN-30	Millett	330218	813607	01/12/91	7.4			Well no longer in use
Calhoun	037-005	Morgan	313518	843349	07/18/91	8.48	08/17/93	<0.1	Fertilizer from up gradient cultivated fields
Candler	BM-2	Metter	322744	820152	10/21/90	5.1	02/16/94	7.6	Fertilizer from up gradient cultivated fields
Candler	BM-3	Metter	322712	820238	10/21/90	7.0	02/18/94	8.5	Fertilizer from up gradient cultivated field
Candler	CH-5	Twin City SE	323237	820526	10/20/90	6.0	01/10/94	1.3	Possible fertilizer from up gradient cultivated field
Candler	CR-8	Cobbtown	321825	820753	10/20/90	7.5	09/23/93	9.76	Fertilizer from up gradient field/animal waste from pasture
Candler	N-12	Metter SE	321757	820636	10/20/90	>10.0	01/14/93	22.8	Fertilizer; poor well construction
Candler	043-001	Metter	322235	820034	02/26/91	16.7	02/18/94	1.7	Could not determine source
Cherokee	057-012	Canton	341311	842830	07/28/92	11.0	04/20/94	29.9	Up gradient chicken houses
Cherokee	057-013	Canton	341338	842810	07/28/92	7.0	05/18/94	8.5	Up gradient chicken houses
Cherokee	057-022	Fairmount	342338	843803	07/30/92	10.5	05/05/94	20.6	Chicken houses/horse pasture
Clay	B-401	Fort Gaines NE	314300	850348	08/01/91	5.0	11/22/93	1.3	Up gradient pig enclosure
Clay	JCH-258	Fort Gaines	313309	850106	07/31/91	6.0	04/11/94	<0.2	Could not determine source
Clay	061-001	Fort Gaines NE	314129	850258	05/07/91	8.0	11/22/93	0.7	Up gradient pig enclosure
Clayton	063-008	Jonesboro	333314	842156	10/06/92	5.0			Well not in operation at time of re-test
Clayton	063-009	Jonesboro	333442	841752	10/06/92	5.0	01/12/94	1.8	Possible fertilizer from gardens surrounding well
Clayton	063-013	Hampton	332910	842226	10/07/92	5.0	08/23/93	1.6	Possible fertilizer from gardens surrounding well
Clayton	063-021	Jonesboro	333453	841554	10/06/92	5.0			Owner refused re-test
Cobb	067-006	Mountain Park	340240	842946	06/22/92	10.0	09/27/93	10.16	Possible fertilizer from garden/lawn near well
Coffee	AJW-4	Douglas North	313606	824655	09/28/91	6.27	08/16/93	3.8	Possible fertilizer from agricultural activity

APPENDIX B: RESAMPLED WELL DATA

COUNTY	WELL I.D.	QUADRANGLE	LATITUDE	LONGITUDE	TEST DATE	ORIGINAL NITRATE (N) VALUE	RE-TEST DATE	RE-TEST NITRATE (N) VALUE	NITRATE POLLUTION SOURCE/COMMENTS
Coffee	CR-396	Nicholls	313253	823835	09/29/91	6.0	10/27/93	0.22	Could not determine source
Coffee	DJ-5	Nicholls	313638	824215	09/28/91	10.0	12/22/92	15.9	Poor well construction; possible fertilizer
Coffee	MI-006	Wilsonville	312405	824129	12/04/90	14.0	01/21/94	0.6	Possible fertilizer from cultivated fields
Coffee	069-001	Douglas North	313305	824820	07/15/91	10.0			Unable to locate well for re-test
Colquitt	071	Coolidge	310610	834704	10/10/90	9.2	08/11/93	<0.1	Possible fertilizer from cultivated fields
Colquitt	071-001	Coolidge	310224	835145	06/27/91	9.1	08/11/93	<0.1	Possible fertilizer from up gradient cultivated fields
Cook	075-003	Adel	311255	832900	05/08/91	35.0	12/08/93	0.9	Possible fertilizer from up gradient cultivated fields
Coweta	077-012	Whitesburg	332450	845306	06/09/92	10.5	09/29/93	8.02	Possible fertilizer or animal wastes
Coweta	077-031	Sharpsburg	331840	844105	06/18/92	5.0	08/25/93	1.42	Possible animal wastes from horse pasture
Crisp	B-350	Cordele	315720	834947	07/09/91	10.0	12/28/92	9.8	Possible fertilizer
Crisp	M-1026	Penia	315526	833802	07/03/91	>10.0	12/28/92	5.4	Poor well construction - bucket drawn, no pump
Crisp	081-005	Cordele	315307	835207	01/15/91	11.0	12/16/93	2.4	Possible fertilizer
Dawson	085-001	Dawsonville	342324	840315	09/10/92	5.0	10/18/92	0.1	Poultry wastes
Dawson	085-002	Dawsonville	342340	840319	09/10/92	5.0	05/18/94	5.18	Could not determine source
Decatur	MN-202	Steinham Store	310411	843216	08/28/91	7.0	07/13/93	12.0	Fertilizer from lawn/pecan trees/cultivated field
Decatur	ND-28	Mount Pleasant	304241	844013	08/26/91	6.0	07/13/93	9.6	Fertilizer; poor well construction
Decatur	087-001	Boykin	310303	843822	06/25/91	8.2	08/18/93	<0.1	Irrigation of up gradient fields
Decatur	087-002	Brinson	305500	843909	06/25/91	5.83			Unable to locate well for re-test
Dooly	093	Byromville	321025	835844	08/20/91	5.7	10/14/93	0.1	Fertilizer
Early	AJ-456	Damascus	311638	844414	08/15/91	9.0	08/18/93	<0.1	Irrigation of up gradient fields
Evans	B-31	Glissons Millpond	320643	814827	01/27/91	>10.0	01/14/93	21.5	Poor well construction/casing
Evans	B-32	Deans Crossing	320539	815304	11/25/90	5.0	02/03/94	0.7	Possible fertilizer; poor well maintenance
Evans	B-38	Daisy	321259	814908	12/01/90	6.0	01/07/94	<0.2	Poor well construction
Evans	BJ-2	Claxton	321309	815508	11/24/90	6.0			House unoccupied, no power to well pump
Evans	BJ-4	Glissons Millpond	320538	815137	11/29/90	5.0	01/13/94	<0.2	Fertilizer from up gradient cultivated fields
Evans	CH-33	Claxton	321334	815310	12/02/90	5.8	09/23/93	10.87	Fertilizer from fields across road
Evans	CR-43	Deans Crossing	320627	815354	11/27/90	11.1			No re-test - owner drilled new, deeper well
Evans	N-65	Claxton	321334	815832	12/07/90	6.0			Owner refused re-test
Fayette	113-001	Fairburn	333114	843000	08/11/92	6.0	08/24/93	0.66	Possible fertilizer from garden
Fayette	113-015	Tyrone	332907	843059	08/12/92	5.0	05/31/94	4.5	Could not determine source
Fayette	113-022	Fayetteville	332300	842452	08/18/92	5.0	08/24/93	4.8	Poor well construction
Floyd	115-009	Wax	341233	850355	10/08/92	7.6	01/26/94	8.6	Possible animal waste from up gradient cattle pastures
Floyd	115-010	Wax	341230	850406	10/08/92	6.4	01/26/94	7.7	Possible animal waste from surrounding cattle pasture
Forsyth	117-005	Duluth	340716	841325	08/20/92	7.0	08/26/93	>9.9	Well located down gradient from two chicken houses
Forsyth	117-013	Cumming	341138	841410	08/20/92	5.0	08/20/93	<0.1	Possible fertilizer from cultivated fields
Forsyth	117-029	Matt	341856	840832	09/03/92	7.0	08/19/93	2.5	Possible poultry waste
Forsyth	117-030	Matt	341856	840829	09/03/92	9.0	08/19/93	2.5	Possible poultry waste
Franklin	119-014	Carnesville	341530	831354	05/14/93	11.1	09/14/93	5.57	Fertilized garden located up gradient from well site
Fulton	121-013	Palmetto	333705	843856	07/14/92	10.5	08/26/93	6.55	Poor well construction/old dairy farm
Fulton	121-028	Birmingham	341040	841617	08/10/92	10.0	09/21/93	0.75	Well down gradient from neighbor's septic tank
Grady	131-001	Cairo North	305806	841435	05/26/91	5.17	11/23/93	0.8	Fertilizer from up gradient cultivated field
Grady	131-002	Cairo North	305910	841453	06/26/91	5.89	08/11/93	<0.1	Possible fertilizer from up gradient fields
Greene	133-007	Greensboro	333408	831434	02/11/93	5.8	08/25/93	4.2	Possible animal waste from up gradient enclosure
Greene	133-019	Greensboro	333404	830935	02/18/93	5.8	02/03/94	5.4	Possible influence from up gradient septic systems
Gwinnett	135-028	Norcross	335846	841245	09/04/92	6.0	09/21/93	12.19	Well site in middle of heavily-fertilized garden
Habersham	137-009	Lake Burton	344528	833525	11/28/92	7.0	10/27/93	3.2	Could not determine source
Hall	139-011	Chestnut Mountain	341407	834515	06/05/92	8.4	10/19/93	7.6	Possible animal waste/poor well construction
Hancock	141-005	White Plains	332635	830240	02/23/93	58.0	09/09/93	66.6	Animal waste from poultry, horses, cattle

APPENDIX B: RESAMPLED WELL DATA

COUNTY	WELL I.D.	QUADRANGLE	LATITUDE	LONGITUDE	TEST DATE	ORIGINAL NITRATE (N) VALUE	RE-TEST DATE	RE-TEST NITRATE (N) VALUE	NITRATE POLLUTION SOURCE/COMMENTS
Hart	147-001	Hartwell	342159	825933	05/03/93	9.4	09/13/93	4.76	Possible fertilizer from up gradient garden/fields
Hart	147-002	Hartwell	342159	825932	05/03/93	7.8	09/13/93	7.22	Possible fertilizer from up gradient garden/fields
Hart	147-004	Hartwell	342113	825926	05/03/93	16.0	08/17/93	2.5	Possible animal waste from up gradient poultry pen
Henry	151-021	Ola	332534	840420	08/24/92	5.1	10/05/93	1.47	Possible septic
Henry	151-039	Stockbridge	333628	841255	09/01/92	5.0	10/05/93	2.04	Possible animal waste from chicken houses
Irwin	155-007	Fitzgerald West	313840	831508	10/09/90	7.7	12/03/93	10.0	Fertilizer from garden/hay field
Irwin	155-032	Ocilla West	313334	831508	04/10/91	28.6	12/03/93	5.5	Possible fertilizer from up gradient fields
Jackson	157-017	Commerce	341316	832945	01/27/92	9.1	08/04/93	1.0	Could not determine source
Jackson	157-018	Pendergrass	341014	834258	02/03/92	5.2	08/04/93	0.2	Could not determine source
Jasper	159-014	Lloyd Shoals Dam	332029	834525	11/12/92	6.0	12/29/93	14.2	Well site down gradient from fertilized garden
Jeff Davis	161-001	Grays Landing	315427	822911	06/03/91	6.0	12/21/93	6.3	Animal waste from up gradient cattle pasture
Jefferson	B-111	Matthews	331457	821751	01/20/91	5.0	05/09/94	2.2	Could not determine source
Jefferson	B-143	Wrens	330916	822815	02/09/91	5.0	05/09/94	2.0	Possible animal waste/fertilizer
Jefferson	BJ-22	Matthews	331235	822130	01/21/91	9.23	10/13/93	0.2	Could not determine source
Jefferson	163-008	Louisville	330723	822703	12/13/90	8.4	12/20/93	1.0	Possible animal waste/fertilizer
Jenkins	BM-11	Garfield	324019	820346	12/11/90	9.0			Unable to locate well for re-test
Johnson	167-002	Cow Hell Swamp	324357	825433	02/13/91	>10.0	11/29/93	<0.2	Possible animal waste from up gradient farm
Jones	169-027	Macon NE	325648	833058	04/29/93	9.0	02/07/94	2.7	Possible animal waste from cattle
Laurens	MA-68	Lowery	322144	824837	03/17/91	9.0			Well no longer in use - house abandoned
Laurens	N-109	Cadwell	321713	830027	01/03/91	5.0	05/06/94	2.8	Possible fertilizer; poor well construction
Laurens	175-001	Minter	322620	824747	02/05/91	5.0	04/21/94	<0.2	Possible fertilizer from small garden
Lee	PA-047	Leesburg	313807	840930	03/18/92	6.5	08/17/93	<0.1	Possible fertilizer/irrigation/septic
Lincoln	181-022	Lincolnton	334725	822615	02/19/93	5.0	02/02/94	6.8	Well site down gradient from garden/animal enclosures
Long	ND-20	Glennville SE	314647	825120	08/04/91	7.0			Well no longer in use
Long	ND-21	Glennville SW	315140	815344	08/04/91	5.0	08/05/93	4.34	Possible fertilizer from up gradient cultivated field
McDuffie	189-002	Thomson West	332831	823434	08/06/92	9.5	08/23/93	<0.1	Possible animal waste from past farming activity
McDuffie	189-032	Wrightsboro	333149	823215	08/21/92	9.0	08/24/93	2.0	Possible animal waste from past dairy operation
Macon	B-331	Andersonville	321351	840950	07/01/91	5.0	12/02/93	0.51	Fertilizer from surrounding cultivated fields
Macon	CH-517	Ideal South	322102	840903	07/02/91	6.0	12/06/93	2.55	Could not determine source
Macon	CH-519	Ideal South	321557	840859	07/02/91	5.0	12/06/93	1.4	Could not determine source
Macon	M-1020a	Marshallville SW	321857	835939	07/02/91	>10.0	09/07/93	12.0	Could not determine source
Macon	M-1021	Marshallville SW	321719	835706	07/02/91	8.0	12/06/93	2.01	Fertilizer from cultivated field across road
Macon	M-1022	Marshallville	322859	835829	07/02/91	5.0	09/07/93	0.7	Could not determine source
Macon	193-001	Ideal North	322430	840750	01/07/91	7.48	10/12/93	0.1	Fertilizer
Macon	193-002	Marshallville SW	321832	835932	01/07/91	6.6	07/21/93	0.6	Possible fertilizer or animal waste
Macon	193-049	Garden Valley	322500	840116	10/04/93	17.4	04/08/94	5.7	Possible fertilizer; poor well construction
Macon	193-050	Garden Valley	322343	840352	10/04/93	11.0	04/08/94	3.8	Could not determine source
Madison	195-019	Hull	340557	831614	10/02/92	11.5	10/21/93	16.8	Animal waste from up gradient pasture
Meriwether	199-003	Haralson	330837	843138	05/20/93	5.0	05/19/94	2.45	Well located in active pasture
Meriwether	199-009	Warm Springs	325238	843838	05/27/93	5.0	05/19/94	6.8	Could not determine source
Miller	201-004	Colquitt	311320	844132	07/17/91	8.9	08/10/93	<0.1	Animal waste from dog and swine enclosures
Miller	201-005	Colquitt	311445	844109	07/17/91	7.73	08/10/93	<0.1	Fertilizer
Mitchell	205-001	Branchville	311429	841856	03/28/91	8.34	12/15/93	1.8	Fertilizer from up gradient cultivated fields
Monroe	207-010	East Juliette	330632	834809	04/13/93	5.0	05/17/94	4.06	Could not determine source
Monroe	207-028	Smarr	325739	835724	05/13/93	5.8	02/14/94	2.9	Animal waste
Montgomery	B-65	Vidalia	321332	822841	12/18/90	10.0	05/17/94	1.2	Fertilizer from up gradient cultivated fields
Montgomery	B-67	Vidalia	320852	822847	12/18/90	7.0	10/18/93	0.54	Possible fertilizer; poor well construction
Montgomery	D-33	Uvalda	320427	823241	12/15/90	5.2	10/18/93	0.56	Fertilizer from up gradient cultivated field

APPENDIX B: RESAMPLED WELL DATA

COUNTY	WELL I.D.	QUADRANGLE	LATITUDE	LONGITUDE	TEST DATE	ORIGINAL NITRATE (N) VALUE	RE-TEST DATE	RE-TEST NITRATE (N) VALUE	NITRATE POLLUTION SOURCE/COMMENTS
Montgomery	N-97	Soperton South	321735	823345	12/18/90	10.0			House unoccupied
Montgomery	209-001	Soperton South	321923	823125	05/22/91	5.3	02/15/94	1.3	Possible fertilizer from garden/landscaping
Morgan	211-028	Rutledge South	333450	833145	07/01/93	32.0	05/31/94	28.6	Dairy operation
Newton	217-023	Covington	333530	834931	07/14/92	12.0	10/04/93	1.7	Could not determine source
Oconee	219-003	High Shoals	335222	833155	01/07/92	7.0	08/18/93	<0.1	Fertilizer from up gradient irrigated fields
Oconee	219-017	Watkinsville	335030	832918	01/14/92	5.4	08/16/93	<0.1	Possible fertilizer from up gradient fields
Oglethorpe	221-014	Carlton	340008	830605	10/05/92	5.1	09/14/93	6.5	Animal waste from surrounding cattle enclosure
Paulding	223-012	Nebo	335127	844856	06/29/92	7.0	09/27/93	2.12	Animal waste from surrounding cattle pasture
Paulding	223-013	Nebo	335125	844900	06/29/92	6.0	09/27/93	2.77	Could not determine source
Paulding	223-014	Dallas	335255	845024	06/29/92	7.0			No re-test, now connected to county water system
Paulding	223-032	Nebo	334659	845128	08/24/93	30.2	03/16/94	29.5	Animal waste from surrounding horse pasture
Pickens	227-022	Ludville	342805	843104	09/29/92	5.0			No re-test due to recent tornado damage to home
Pickens	227-023	Ludville	342828	843046	09/29/92	6.0	10/22/93	0.58	Could not determine source
Pickens	227-025	Ludville	342608	843355	09/29/92	5.0	10/22/93	0.62	Possible animal waste from surrounding cattle pasture
Pierce	CR-303	Patterson	312544	820855	08/10/91	5.0	02/10/94	4.6	Fertilizer from up gradient garden/field
Pierce	D-100	Blackshear West	311848	822109	08/10/91	5.6	02/09/94	<0.2	Could not determine source
Pierce	D-101	Mershon	312520	822158	08/10/91	9.9			House unoccupied - no power to well pump
Pierce	ND-23	Blackshear West	311657	821824	08/11/91	>10.0	12/23/92	13.5	Possible fertilizer
Pierce	ND-24	Patterson	312252	821445	08/11/91	6.0	02/10/94	7.7	Fertilizer from up gradient cultivated field
Pierce	229-001	Patterson	312249	821348	07/25/91	8.38			Unable to locate well for re-test
Pierce	229-002	Blackshear East	312223	821352	08/19/92	>10.0	02/08/94	20.5	Owner reports septic tank leakage problems
Polk	233-003	Cedartown East	340356	851358	07/13/92	9.0	09/28/93	0.75	Could not determine source
Polk	233-007	Cedartown East	340258	851113	07/13/92	11.0	09/27/93	2.72	Animal waste from surrounding horse/cow pastures
Polk	233-008	Cedartown East	340242	851111	07/13/92	7.0	09/27/93	4.0	Possible fertilizer or animal waste
Quitman	M-1069	Hatcher	314635	850336	07/30/91	9.4	01/27/94	9.0	Fertilizer from cultivated field across road
Randolph	BJ-80	Benevolence	315433	844110	07/19/91	5.0	12/07/93	0.32	Could not determine source
Randolph	CH-569	Cuthbert	314800	844710	07/17/91	8.6	12/23/93	<0.2	Fertilizer
Randolph	M-1055	Shellman	314753	843613	07/18/91	5.0	04/11/94	2.6	Fertilizer
Randolph	243-005	Shellman	314530	843657	08/14/91	8.3	08/20/93	2.3	Possibly from septic tanks in city
Screven	CR-59	Sylvania South	324145	813833	12/02/90	5.0	04/18/94	1.4	Poor well construction
Seminole	253-003	Donalsonville East	310340	844935	06/11/91	6.35	08/19/93	<0.1	Fertilizer from up gradient irrigated fields
Spalding	255-024	Griffin South	331230	842000	11/02/92	5.0	08/20/93	4.0	Possible animal waste; poor well construction
Stephens	257-013	Toccoa	343239	831613	06/02/93	24.3	09/07/93	47.38	Animal waste from up gradient pasture; fertilizer
Stewart	BJ-93	Twin Springs	320253	850213	07/23/91	8.0			Unable to locate well for re-test
Stewart	BJ-98	Richland	320225	843911	07/24/91	5.0	09/23/93	0.2	Animal waste from pig enclosure
Stewart	M-1056	Richland	320403	843913	07/22/91	5.0	09/23/93	0.4	Possible septic
Stewart	M-1062	Lumpkin SW	320354	845339	07/24/91	8.4	01/04/94	1.8	Poor well construction
Stewart	M-1063	Twin Springs	320515	850258	07/25/91	>10.0	12/15/92	14.5	Possible fertilizer
Stewart	M-1064	Twin Springs	320523	850228	07/25/91	8.0	01/27/94	<0.2	Could not determine source
Stewart	MJ-73	Sanford	315840	845636	07/27/91	>10.0	12/15/92	4.8	Possible septic or fertilizer
Sumter	CR-266	Bottsford	315853	842622	06/20/91	9.8	12/02/93	3.8	Animal waste from up gradient horse pasture
Sumter	261-001	Lake Collins	320326	841634	07/02/91	7.0	09/22/93	0.55	Could not determine source
Sumter	261-007	Ellaville South	320802	841805	10/23/90	6.3	12/13/93	1.06	Possible animal waste
Taliaferro	265-011	Crawfordville	333129	825804	04/07/93	8.4	02/03/94	11.4	Possible poultry/cattle animal waste
Tattnall	B-1	Reidsville East	320558	820417	11/04/90	7.0	02/03/94	7.9	Fertilizer; poor well construction
Tattnall	B-3	Reidsville West	320305	821133	11/04/90	7.0			Unable to locate well for re-test
Tattnall	B-5	Reidsville West	320152	821143	11/10/90	8.0	01/06/94	<0.2	Poor well construction; possible fertilizer
Tattnall	B-10	Reidsville East	320108	820427	11/10/90	6.0			Well not currently in use - house unoccupied

APPENDIX B: RESAMPLED WELL DATA

COUNTY	WELL I.D.	QUADRANGLE	LATITUDE	LONGITUDE	TEST DATE	ORIGINAL NITRATE (N) VALUE	RE-TEST DATE	RE-TEST NITRATE (N) VALUE	NITRATE POLLUTION SOURCE/COMMENTS
Tattnall	CB-20	Reidsville East	320245	820212	11/21/90	7.0	02/04/94	2.7	Fertilizer from up gradient cultivated field
Tattnall	CB-23	Glennville	315504	815751	11/21/90	9.0			Unable to locate well for re-test
Tattnall	CR-35	Collins	320754	820327	11/18/90	7.0	09/24/93	4.1	Possible fertilizer or septic
Tattnall	CR-36	Reidsville East	320424	820303	11/18/90	5.0	02/03/94	5.3	Fertilizer and animal waste
Tattnall	CR-38	Reidsville East	320247	820331	11/18/90	7.0			Well no longer in use - house unoccupied
Tattnall	CR-40	Deans Crossing	320240	815442	11/24/90	9.0	02/02/94	<0.2	Possible fertilizer
Tattnall	CR-41	Deans Crossing	320200	815540	11/24/90	5.4			Well no longer in use - new, deeper well in use
Tattnall	MB-1	Reidsville East	320428	820240	11/11/90	9.0			Well no longer in use - mobile home moved from site
Tattnall	MB-2	Collins	321305	820139	11/11/90	5.0	03/11/94	8.3	Fertilizer from surrounding cultivated fields
Tattnall	N-51	Glennville	315926	815338	11/20/90	7.0	01/07/94	3.6	Possible fertilizer or animal waste
Tattnall	N-52	Glennville	315845	815703	11/20/90	7.0	08/11/93	10.5	Possible animal waste from up gradient pastures
Telfair	B-211	Snipesville	315206	824757	04/20/91	9.0	10/18/93	<0.2	Fertilizer from up gradient cultivated fields
Telfair	BJ-55	Scotland	320141	824940	04/07/91	6.0	10/18/93	<0.2	Possible fertilizer or animal waste
Telfair	CR-205	McRae	320150	825818	04/13/91	10.0	12/22/92	11.3	Animal waste from swine enclosure
Telfair	271-001	McRae	320134	825450	02/07/91	30.8			Well apparently no longer in use
Terrell	M-1046	Shellman	314822	843605	07/15/91	5.0	04/11/94	3.2	Could not determine source
Thomas	BJ-204	Meigs	310406	840326	09/12/91	6.0	12/14/93	3.3	Fertilizer from up gradient garden and field
Thomas	CR-368	Merrillville	305721	835434	09/11/91	10.0	12/16/92	12.6	Fertilizer; poor well construction
Thomas	275-001	Thomasville	305206	835550	08/08/91	>10.0	08/12/93	<0.1	Animal waste; fertilizer; poor well construction
Thomas	275-002	Boston	304920	834824	08/08/91	9.8	08/12/93	<0.1	Fertilizer
Thomas	275-003	Thomasville	305126	835456	08/08/91	9.08			Unable to locate well for re-test
Tift	277-003	Tifton West	312607	833413	09/10/91	6.76	12/03/93	0.2	Possible fertilizer
Toombs	B-53	Lyons	321013	821735	12/12/90	5.0	05/06/94	1.7	Could not determine source
Toombs	B-60	Johnson Corner	320531	821847	12/13/90	>10.0	01/25/93	22.5	Fertilizer
Toombs	BA-52	Johnson Corner	320517	821645	12/14/90	9.0	10/19/93	<0.2	Possible fertilizer; owner plans new, deeper well
Toombs	BD-21	Alston	320448	822313	12/17/90	>10.0	04/19/94	31.7	Fertilizer from fields and garden
Toombs	BD-22	Alston	320416	822457	12/17/90	10.0	01/25/93	1.5	Fertilizer
Toombs	CN-27	Oak Park SW	321854	822416	12/14/90	8.0	10/19/93	<0.2	Could not determine source
Toombs	N-83	Vidalia	320827	822255	12/12/90	7.0	01/03/94	0.3	Could not determine source
Toombs	N-86	Vidalia	320748	822314	12/13/90	5.6	01/03/94	0.4	Fertilizer
Toombs	279-001	Oak Park	321547	821558	05/22/91	10.0	01/20/94	0.4	Fertilizer
Treutlen	N-34	Rockledge	322428	824013	11/10/90	6.0	05/17/94	1.8	Could not determine source
Treutlen	283-001	Soperton South	322051	823011	05/22/91	7.0	02/18/94	0.29	Possible fertilizer from cultivated fields
Turner	287-001	Chula	313603	833528	08/05/91	5.28			Well no longer in use - has new, deeper well
Turner	287-002	Ashburn	314002	833731	08/05/91	5.45	10/13/93	>10.0	Animal waste or fertilizer
Turner	287-004	Ashburn	314417	834405	08/05/91	>10.0	10/13/93	21.25	Animal waste
Upson	293-007	Thomaston	325923	841625	05/07/92	9.5	01/28/94	7.1	Well site down gradient from fertilized garden
Walton	297-032	Bold Springs	335232	834833	11/20/92	13.0	10/07/93	7.76	Animal waste from pasture; possible septic
Walton	297-033	Bold Springs	335254	834740	11/12/92	7.0	10/07/93	7.81	Animal waste from surrounding horse pasture
Warren	301-032	Sparta NE	332620	824604	04/13/93	6.0	09/17/93	1.15	Possible fertilizer
Wayne	N-329	Ritch	313157	820530	07/13/91	5.0	02/08/94	6.7	Fertilizer from up gradient cultivated fields
Wayne	N-333	Ritch	313607	820047	07/13/91	6.0	02/08/94	10.1	Fertilizer from up gradient cultivated fields
Wayne	N-340	Hortense	312208	815750	07/21/91	7.0	02/07/94	7.4	Fertilizer from up gradient cultivated fields
Webster	307-001	Parrott	315857	843155	07/03/91	6.78	12/07/93	5.2	Fertilizer from cultivated fields
Wheeler	B-213	Jordan	320255	824320	04/20/91	10.0	12/28/92	14.0	Possible animal waste
Wheeler	CR-209	Scotland	320510	824656	04/20/91	9.6			Well no longer in use - house unoccupied
Wilkes	317-029	Jacksons Crossroads	335517	824517	09/28/92	5.3	02/02/94	5.7	Possible animal waste or fertilizer
Worth	321-002	Bridgeboro	312408	835811	07/14/92	>10.0	04/12/94	18.0	Fertilizer from fields surrounding house

Appendix C

Low Flow Stream Sampling Data

APPENDIX C: LOW FLOW STREAM SAMPLING DATA

COUNTY	SITE I.D.	STREAM NAME (If known)	ROAD INTERSECTION	QUADRANGLE	LATITUDE	LONGITUDE	DATE SAMPLED	NITRATE (N) - mg/l
Barrow	013-001	Mulberry River	Liberty Church Road	Auburn	340649	834854	09/13/94	2.5
Barrow	013-002	Duncan Creek	Georgia Highway 211	Auburn	340632	834858	09/13/94	2.1
Barrow	013-003	Little Mulberry River	Old Thompson Mill Road	Auburn	340343	834707	09/13/94	2.2
Barrow	013-004	Little Mulberry River	Boss Hardy Road	Auburn	340339	834814	09/13/94	1.98
Barrow	013-005	Rock Creek	Boss Hardy Road	Auburn	340319	834752	09/13/94	2.4
Barrow	013-006	Little Mulberry River	Dee Kennedy Road	Auburn	340319	834929	09/13/94	2.9
Barrow	013-007	Rock Creek	Dee Kennedy Road	Auburn	340257	834856	09/13/94	1.2
Barrow	013-008	Rock Creek	Mt. Moriah Road	Auburn	340151	835015	09/13/94	1.9
Barrow	013-009	Mulberry River	Covered Bridge Road	Auburn	340442	834635	09/13/94	1.4
Barrow	013-010	Cedar Creek	City Pond Road	Winder North	340042	834421	09/14/94	1.11
Barrow	013-011	Cedar Creek	Miles Patrick Road	Winder North	340054	834322	09/14/94	1.2
Barrow	013-012	Rocky Creek	Mulberry Road	Winder North	340308	834333	09/14/94	1.15
Barrow	013-013	Mulberry River	Georgia Highway 53	Winder North	340317	834302	09/13/94	1.37
Barrow	013-014	Hawk Creek	Georgia Highway 53	Winder North	340235	834257	09/14/94	1.7
Barrow	013-015	Cedar Creek	Georgia Highway 53	Winder North	340147	834245	09/14/94	1
Barrow	013-016	Cedar Creek	Rockwell Church Road	Winder North	340222	834147	09/14/94	2.1
Barrow	013-017	Mulberry River	Georgia Highway 11	Winder North	340307	833948	09/13/94	1.9
Barrow	013-018	Mulberry River	Hancock Road	Winder North	340246	833805	09/13/94	1.7
Barrow	013-019	Barber Creek	Finch Drive	Winder North	340230	833756	09/13/94	1.57
Barrow	013-020	Beech Creek	Dunahoo Road	Winder North	340050	834003	09/13/94	3.1
Barrow	013-021	unnamed tributary of Beech Creek	Holsenbeck School Road	Winder North	340017	834019	09/15/94	2.5
Barrow	013-022	Beech Creek	Ross Road	Jefferson	340043	833702	09/15/94	2.21
Barrow	013-023	Beech Creek	Georgia Highway 211	Jefferson	340112	833622	09/13/94	0.9
Barrow	013-024	Mulberry River	Double Bridges Road	Jefferson	340216	833518	09/13/94	1.1
Barrow	013-025	Middle Oconee River	Georgia Highway 82	Jefferson	340154	833348	09/13/94	1.3
Barrow	013-026	Apalachee River	Brown Bridge Road	Bold Springs	335917	835044	09/14/94	1.1
Barrow	013-027	Apalachee River	Kilcrease Road	Bold Springs	335750	834927	09/14/94	0.9
Barrow	013-028	Apalachee River	Patrick Mill Road	Bold Springs	335711	834846	09/14/94	2.3
Barrow	013-029	Williamson Creek	Patrick Mill Road	Bold Springs	335805	834726	09/14/94	2.7
Barrow	013-030	Williamson Creek	Haymon Morris Road	Bold Springs	335702	834648	09/14/94	1.9
Barrow	013-031	Williamson Creek	Tom Miller Road	Bold Springs	335545	834708	09/14/94	1.62
Barrow	013-032	Apalachee River	Georgia Highway 81	Bold Springs	335457	834653	09/14/94	0.91
Barrow	013-033	Apalachee River	Tanners Bridge Circle	Bold Springs	335350	834529	09/14/94	1.11
Barrow	013-034	Apalachee River	Georgia Highway 11	Winder South	335401	834325	09/14/94	1.3
Barrow	013-035	unnamed tributary of Apalachee River	Georgia Highway 11	Winder South	335427	834317	09/14/94	1.2
Barrow	013-036	Apalachee River	McElhannon Road	Bold Springs	335433	834153	09/14/94	1.8
Barrow	013-037	Marburg Creek	Georgia Highway 11	Winder South	335731	834313	09/14/94	1.6
Barrow	013-038	unnamed tributary of Beech Creek	Georgia Highway 82	Winder South	335932	834100	09/15/94	3.2
Barrow	013-039	Marburg Creek	Smith Mill Road	Winder South	335611	834130	09/14/94	1.1
Barrow	013-040	Marburg Creek	Sand Pump Road	Winder South	335534	834011	09/15/94	2.53
Barrow	013-041	Apalachee River	Smith Chapel Road	Winder South	335430	833915	09/15/94	2.3
Barrow	013-042	Marburg Creek	Manning Gin Road	Winder South	335444	833847	09/15/94	2.12
Barrow	013-043	Beech Creek	Pleasant Hill Church Road	Winder South	335952	833813	09/15/94	2.9
Barrow	013-044	Barber Creek	Statham Road	Statham	335655	833643	09/15/94	1.45
Barrow	013-045	Barber Creek	Robertson Bridge Road	Statham	335635	833621	09/15/94	2.3
Barrow	013-046	Bear Creek	Arnold Road	Statham	335856	833357	09/14/94	2.2
Barrow	013-047	Bear Creek	Lois Kinney Road	Statham	335932	833305	09/14/94	1.7
Barrow	013-048	unnamed tributary of Bear Creek	Bogart-Jefferson Road	Statham	335806	833318	09/15/94	1.61
Barrow	013-049	Little Bear Creek	Bogart-Jefferson Road	Statham	335747	833234	09/15/94	1.77
Barrow	013-050	Cedar Creek	Georgia Highway 211	Auburn	340024	834520	09/14/94	0.7
Barrow	013-051	Mulberry River	Georgia Highway 124	Auburn	340601	834732	09/13/94	2.6
Barrow	013-052	unnamed tributary of Apalachee River	Briscoe Mill Road	Winder South	335448	834421	09/14/94	1.73
Barrow	013-053	unnamed tributary of Apalachee River	Arch Tanner Road	Winder South	335437	834340	09/14/94	1.66
Barrow	013-054	Marburg Creek	Harrison Mill Road	Winder South	335638	834213	09/14/94	1.48
Barrow	013-055	unnamed tributary of Marburg Creek	Jackson Trail Road	Winder South	335652	834029	09/15/94	3.3
Barrow	013-056	unnamed tributary of Marburg Creek	Jackson Trail Road	Winder South	335717	834011	09/15/94	1.31
Barrow	013-057	unnamed tributary of Marburg Creek	Smith Sisters Road	Winder South	335505	833835	09/15/94	2.96
Barrow	013-058	Barber Creek	Wall Road	Winder South	335730	833758	09/15/94	1.68
Barrow	013-059	unnamed tributary of Little Mulberry River	Fleeman Road	Auburn	340324	834926	09/13/94	2.7
Barrow	013-060	unnamed tributary of Little Mulberry River	Mt. Moriah Road	Auburn	340323	835053	09/13/94	3
Barrow	013-061	Rock Creek	Parks Mill Road	Auburn	340150	834936	09/13/94	1.2
Barrow	013-062	unnamed tributary of Apalachee River	Brown Bridge Road	Bold Springs	335923	835031	09/14/94	1.1
Barrow	013-063	unnamed tributary of Marburg Creek	Georgia Highway 11	Winder South	335635	834305	09/14/94	1.04
Barrow	013-064	unnamed tributary of Apalachee River	Yearwood Road	Winder South	335453	834205	09/14/94	1.57
Barrow	013-065	unnamed tributary of Little Bear Creek	Luke Circle	Statham	335730	833305	09/15/94	1.91
Barrow	013-066	unnamed tributary of Bear Creek	Lois Kinney Road	Statham	335938	833303	09/15/94	2.4
Barrow	013-067	unnamed tributary of Bear Creek	Arnold Road	Statham	335944	833402	09/15/94	1.89

APPENDIX C: LOW FLOW STREAM SAMPLING DATA

COUNTY	SITE I.D.	STREAM NAME (if known)	ROAD INTERSECTION	QUADRANGLE	LATITUDE	LONGITUDE	DATE SAMPLED	NITRATE (N) - mg/l
Barrow	013-068	unnamed tributary of Apalachee River	Fred Kilcrease Road	Bold Springs	335815	834841	09/21/94	1.82
Barrow	013-069	unnamed tributary of Apalachee River	Roxey Maxey Road	Bold Springs	335707	834802	09/21/94	1.39
Barrow	013-070	unnamed tributary of Apalachee River	Harvey Lokey Road	Bold Springs	335553	834513	09/21/94	1.34
Barrow	013-071	unnamed tributary of Apalachee River	Briscoe Mill Road	Winder South	335525	834418	09/21/94	1.33
Barrow	013-072	unnamed tributary of Apalachee River	J. B. Owens Road	Bold Springs	335518	834508	09/21/94	1.41
Barrow	013-073	unnamed tributary of Rock Creek	Dee Kennedy Road	Auburn	340216	834807	09/21/94	3.2
Barrow	013-074	unnamed tributary of Rock Creek	County Line-Auburn Road	Auburn	340149	834756	09/21/94	2.75
Barrow	013-075	unnamed tributary of Rock Creek	County Line-Auburn Road	Auburn	340153	834751	09/21/94	2.18
Barrow	013-076	unnamed tributary of Marburg Creek	Golf Course Road	Winder South	335740	834202	09/21/94	1.46
Barrow	013-077	unnamed tributary of Marburg Creek	Corinth Church Road	Winder South	335715	834206	09/21/94	2.71
Barrow	013-078	unnamed tributary of Beech Creek	Lays Road	Winder South	335932	834142	09/21/94	2.5
Barrow	013-079	Beech Creek	Holsenbeck School Road	Winder North	340033	834034	09/21/94	2
Barrow	013-080	unnamed tributary of Cedar Creek	Pendergrass Road	Winder North	340156	834137	09/21/94	2.38
Barrow	013-081	Williamson Creek	Kennedy Sells Road	Bold Springs	335905	834845	09/22/94	1.44
Barrow	013-082	unnamed tributary of Marburg Creek	Bill Rutledge Road	Bold Springs	335905	834522	09/22/94	1.47
Barrow	013-083	unnamed tributary of Marburg Creek	Tucker Road	Bold Springs	335722	834504	09/22/94	2.21
Barrow	013-084	unnamed tributary of Barber Creek	Wall Road	Winder South	335748	833742	09/22/94	2.12
Barrow	013-085	unnamed tributary of Apalachee River	Doster Road	Winder South	335513	833754	09/22/94	1.16
Barrow	013-086	unnamed tributary of Apalachee River	Austin Road	Winder South	335527	833843	09/22/94	2.34
Barrow	013-087	unnamed tributary of Marburg Creek	McCord Road	Winder South	335545	833935	09/22/94	2.21
Barrow	013-088	Apalachee River	Jerico Road	Winder South	335446	833955	09/22/94	2.42
Barrow	013-089	unnamed tributary of Marburg Creek	Tucker Road	Bold Springs	335737	834614	09/22/94	1.71
Barrow	013-090	unnamed tributary of Williamson Creek	Williams Road	Bold Springs	335903	834733	09/22/94	2.91
Barrow	013-091	unnamed tributary of Apalachee River	McElhannon Road	Winder South	335449	834335	09/22/94	2.53
Barrow	013-092	unnamed tributary of Barber Creek	Cosby Road	Winder South	335757	833925	09/22/94	2.21
Barrow	013-093	unnamed tributary of Barber Creek	Edgar Road	Winder South	335821	833927	09/22/94	1.54
Barrow	013-094	unnamed tributary of Beech Creek	Pleasant Hill Church Road	Winder South	335924	833752	09/22/94	1.21
Barrow	013-095	unnamed tributary of Beech Creek	Giles Road	Winder South	335918	833922	09/22/94	2.01
Barrow	013-096	unnamed tributary of Beech Creek	Georgia Highway 82	Jefferson	340011	833602	09/22/94	1.67
Barrow	013-097	unnamed tributary of Beech Creek	Ross Road	Jefferson	340017	833607	09/25/94	1.29
Barrow	013-098	Beech Creek	Bowman Mill Road	Winder South	335954	833832	09/25/94	1.97
Barrow	013-099	unnamed tributary of Beech Creek	Bowman Mill Road	Winder South	335950	833834	09/25/94	2.54
Barrow	013-100	unnamed tributary of Marburg Creek	Bill Rutledge Road	Winder South	335914	834445	09/25/94	1.34
Barrow	013-101	unnamed tributary of Bear Creek	Jefferson Road	Statham	335838	833455	09/25/94	1.18
Barrow	013-102	Rocky Creek	Than Skinner Road	Auburn	340240	834534	09/25/94	1.73
Barrow	013-103	unnamed tributary of Rocky Creek	Will Maynard Road	Auburn	340215	834541	09/25/94	1.76
Barrow	013-104	Rocky Creek	Georgia Highway 211	Auburn	340207	834627	09/25/94	1.42
Barrow	013-105	unnamed tributary of Marburg Creek	Jackson Trail Road	Winder South	335641	834048	09/25/94	2.31
Barrow	013-106	unnamed tributary of Rock Creek	County Line-Auburn Road	Auburn	340127	834831	10/05/94	0.97
Barrow	013-107	unnamed tributary of Little Mulberry River	Cronic Town Road	Auburn	340257	834927	10/05/94	1.13
Barrow	013-108	unnamed tributary of Little Mulberry River	Cronic Town Road	Auburn	340258	834944	10/05/94	1.74
Barrow	013-109	unnamed tributary of Little Mulberry River	Thomas Drive	Auburn	340343	835024	10/05/94	2.21
Barrow	013-110	Barber Creek	Dunahoo Road	Winder North	340144	833930	10/05/94	1.25
Barrow	013-111	unnamed tributary of Beech Creek	Wilbanks Road	Winder North	340102	833950	10/05/94	2.41
Barrow	013-112	unnamed tributary of Beech Creek	Dunahoo Road	Winder North	340102	833955	10/05/94	2
Barrow	013-113	unnamed tributary of Beech Creek	Bowman Mill Road	Jefferson	340102	833713	10/05/94	1.43
Barrow	013-114	unnamed tributary of Apalachee River	Bethlehem Church Road	Winder South	335520	834228	10/05/94	1.72
Barrow	013-115	unnamed tributary of Beech Creek	Cliff Day Road	Winder South	335834	834050	10/06/94	0.93
Barrow	013-116	unnamed tributary of Beech Creek	Wright Street	Winder South	335904	834129	10/06/94	1.09
Barrow	013-117	unnamed tributary of Bear Creek	Jones Road	Jefferson	340102	833415	10/06/94	0.91
Barrow	013-118	unnamed tributary of Mulberry River	Finch Road	Jefferson	340205	833650	10/06/94	1.29
Barrow	013-119	unnamed tributary of Cedar Creek	Sims Road	Winder North	340049	834306	10/06/94	1.63
Barrow	013-120	unnamed tributary of Hawk Creek	Maddox Road	Winder North	340212	834431	10/06/94	2.12
Barrow	013-121	unnamed tributary of Apalachee River	Bethel Church Road	Bold Springs	335540	834554	10/06/94	2.58
Barrow	013-122	unnamed tributary of Apalachee River	Harry McCarty Road	Winder South	335535	834414	10/06/94	1.76
Barrow	013-123	unnamed tributary of Bear Creek	Second Street (Georgia Highway 211)	Statham	335819	833536	10/06/94	1.95
Barrow	013-124	unnamed tributary of Mulberry River	Pleasant Hill Church Road	Winder North	340216	833911	10/06/94	2.14
Lumpkin	187-001	Etowah River	Castleberry Bridge Road	Dawsonville	342821	840212	09/16/94	1.8
Lumpkin	187-002	Gab Creek	Georgia Highway 52	Nimblewill	343201	841059	09/16/94	1.7
Lumpkin	187-003	Poverty Creek	Little Mountain Road	Nimblewill	343131	840935	09/16/94	1.43
Lumpkin	187-004	Chestatee River	Frog Town Road	Neels Gap	343754	835422	09/26/94	1.91
Lumpkin	187-005	Mill Creek	U.S. Highway 19	Neels Gap	343841	835435	09/26/94	1.12
Lumpkin	187-006	Chestatee River	U.S. Highway 19	Neels Gap	343936	835404	09/26/94	1.24
Lumpkin	187-007	Boggs Creek	U.S. Highway 19	Neels Gap	344034	835406	09/26/94	1.39
Lumpkin	187-008	Chestatee River	Georgia Highway 60	Murrayville	343000	835747	09/16/94	1.83
Lumpkin	187-009	Long Branch	Georgia Highway 60	Murrayville	342808	835755	09/16/94	2.11
Lumpkin	187-010	Chestatee River	Georgia Highway 400	Murrayville	342800	835807	09/16/94	1.9

APPENDIX C: LOW FLOW STREAM SAMPLING DATA

COUNTY	SITE I.D.	STREAM NAME (If known)	ROAD INTERSECTION	QUADRANGLE	LATITUDE	LONGITUDE	DATE SAMPLED	NITRATE (N) - mg/l
Lumpkin	187-011	Wahoo Creek	Emory Stephens Road	Cleveland	343056	835105	09/26/94	1.4
Lumpkin	187-012	Chestatee River	Cavender Creek Road	Cleveland	343344	835213	09/26/94	1.01
Lumpkin	187-013	Wahoo Creek	Georgia Highway 52	Cleveland	343005	835206	09/26/94	0.69
Lumpkin	187-014	Cane Creek	Wahsega Road	Campbell Mountain	343437	840102	09/26/94	0.95
Lumpkin	187-015	Clay Creek	Horton Road	Campbell Mountain	343251	840238	09/26/94	1.07
Lumpkin	187-016	unnamed tributary of Clay Creek	Siloam Church Road	Campbell Mountain	343218	840303	09/26/94	1.08
Lumpkin	187-017	Etowah River	Georgia Highway 9	Campbell Mountain	343054	840337	09/26/94	0.98
Lumpkin	187-018	Etowah River	Georgia Highway 52	Campbell Mountain	343205	840347	09/26/94	1
Lumpkin	187-019	Cane Creek	Georgia Highway 9	Campbell Mountain	343148	840024	09/26/94	0.95
Lumpkin	187-020	Yahoola Creek	Duffie Grizzle Road	Dahlonega	343433	835902	09/16/94	1.85
Lumpkin	187-021	Yahoola Creek	U.S. Highway 19	Dahlonega	343353	835930	09/16/94	1.66
Lumpkin	187-022	Yahoola Creek	Wimpy Mill Road	Dahlonega	343243	835845	09/16/94	2.06
Lumpkin	187-023	Yahoola Creek	Georgia Highway 52	Dahlonega	343232	835813	09/16/94	2
Lumpkin	187-024	Yahoola Creek	Georgia Highway 60	Dahlonega	343030	835800	09/16/94	1.7
Lumpkin	187-025	Chestatee River	Georgia Highway 52	Dahlonega	343140	835525	09/16/94	1.72
Lumpkin	187-026	Chestatee River	Rock House Road	Dahlonega	343443	835316	09/16/94	1.26
Lumpkin	187-027	Nimblewill Creek	Nimblewill Church Road	Nimblewill	343333	840829	09/16/94	1.78
Lumpkin	187-028	unnamed tributary of Bull Creek	Pecks Road	Murrayville	342842	835326	09/16/94	1.61
Lumpkin	187-029	Tobacco Pouch Branch	Larmon Forks Road	Campbell Mountain	343152	840443	09/26/94	1.16
Lumpkin	187-030	Mill Creek	Mill Creek Church Road	Campbell Mountain	343033	840641	09/26/94	1.01
Lumpkin	187-031	Nimblewill Creek	Nimblewill Church Road	Campbell Mountain	343310	840635	09/26/94	0.81
Lumpkin	187-032	Bull Creek	St. Paul Church Road	Murrayville	342843	835444	09/16/94	2.01
Lumpkin	187-033	Camp Creek	Ben Higgins Road	Dawsonville	342928	840142	09/16/94	2.02
Lumpkin	187-034	Gab Creek	Wesley Chapel Road	Nimblewill	343247	841050	09/16/94	1.86
Lumpkin	187-035	Wahoo Creek	White Hill Road	Cleveland	343128	835049	09/26/94	0.9
Lumpkin	187-036	Wahoo Creek	Reid Chapman Road	Cleveland	343023	835143	09/26/94	0.9
Lumpkin	187-037	Wahoo Creek	Barnes Mill Road	Clermont	342930	835209	09/26/94	0.49
Lumpkin	187-038	Yahoola Creek	Black Mountain Road	Neels Gap	343812	835955	09/26/94	1.05
Lumpkin	187-039	Robison Creek	Black Mountain Road	Neels Gap	343818	835948	09/26/94	1.04
Lumpkin	187-040	Walker Creek	Yahoola Church Road	Neels Gap	343753	835919	09/26/94	1.17
Lumpkin	187-041	Clay Creek	Clay Creek Falls Road	Campbell Mountain	343216	840119	09/26/94	1.23
Lumpkin	187-042	Mill Creek	Ben West Road	Campbell Mountain	343048	840614	09/26/94	0.9
Lumpkin	187-043	unnamed tributary of Gab Creek	Wesley Chapel Road	Nimblewill	343248	841046	09/16/94	1.86
Lumpkin	187-044	unnamed tributary of Clay Creek	Horton Road	Campbell Mountain	343245	840312	09/26/94	1.09
Lumpkin	187-045	unnamed tributary of Chestatee River	Roy Grindle Road	Dahlonega	343459	835300	09/16/94	1.26
Lumpkin	187-046	Little Cane Creek	Wash Rider Road	Campbell Mountain	343432	840137	09/26/94	0.88
Lumpkin	187-047	unnamed tributary of Cavender Creek	Bamboo Circle	Dahlonega	343337	835631	09/16/94	3.3
Lumpkin	187-048	Etowah River	Hightower Church Road	Campbell Mountain	343536	840442	09/26/94	0.82
Lumpkin	187-049	unnamed tributary of Ward Creek	Luther Head Road	Dahlonega	343357	835732	09/16/94	1.95
Lumpkin	187-050	unnamed tributary of Chestatee River	John Crow Road	Neels Gap	343801	835404	09/27/94	0.65
Lumpkin	187-051	Ward Creek	Cavender Creek Road	Dahlonega	343351	835722	09/16/94	1.52
Lumpkin	187-052	unnamed tributary of Chestatee River	John Crow Road	Neels Gap	343807	835404	09/27/94	0.86
Lumpkin	187-053	unnamed tributary of Gab Creek	Wesley Chapel Road	Nimblewill	343242	841010	09/17/94	1.13
Lumpkin	187-054	unnamed tributary of Chestatee River	John Crow Road	Neels Gap	343830	835348	09/27/94	1.39
Lumpkin	187-055	unnamed tributary of Bull Creek	Mt. Olive Church Road	Murrayville	342902	835347	09/20/94	2.48
Lumpkin	187-056	unnamed tributary of Chestatee River	U.S. Highway 129	Neels Gap	343939	835352	09/27/94	1.51
Lumpkin	187-057	unnamed tributary of Bull Creek	John Garner Road	Murrayville	342923	835336	09/20/94	2.22
Lumpkin	187-058	Waters Creek	Dicks-Waters Creek Road	Neels Gap	343951	835500	09/27/94	0.88
Lumpkin	187-059	unnamed tributary of Bull Creek	Mt. Olive Church Road	Murrayville	342903	835319	09/20/94	2.94
Lumpkin	187-060	unnamed tributary of Mill Creek	Mill Cove Road	Neels Gap	343852	835514	09/27/94	1.3
Lumpkin	187-061	Chestatee River	Long Branch Road Extension	Dahlonega	343238	835316	09/20/94	2.96
Lumpkin	187-062	Mill Creek	Mill Cove Road	Neels Gap	343854	835500	09/27/94	1.15
Lumpkin	187-063	unnamed tributary of Chestatee River	Old Lewis School Road	Dahlonega	343707	835330	09/20/94	2.11
Lumpkin	187-064	unnamed tributary of Mill Creek	Mill Cove Road	Neels Gap	343846	835438	09/27/94	1.13
Lumpkin	187-065	Moose Creek	Porter Springs Road	Dahlonega	343634	835516	09/20/94	2.42
Lumpkin	187-066	Pruitt Creek	Joe Jarrard Road	Neels Gap	343755	835522	09/27/94	1.19
Lumpkin	187-067	unnamed tributary of Tate Creek	Colonel Farrow Drive	Dahlonega	343656	835644	09/20/94	2
Lumpkin	187-068	Jarrard Creek	Stone Pile Gap Road	Neels Gap	343737	835759	09/27/94	1.25
Lumpkin	187-069	unnamed tributary of Tate Creek	Colonel Farrow Drive	Dahlonega	343645	835646	09/20/94	1.81
Lumpkin	187-070	Woody Creek	Walter Caldwell Road	Neels Gap	343855	835931	09/27/94	1.45
Lumpkin	187-071	unnamed tributary of Tate Creek	McDonald Road	Dahlonega	343634	835646	09/20/94	2.43
Lumpkin	187-072	Robison Creek	Jack Walker Road	Neels Gap	343843	835955	09/27/94	1.45
Lumpkin	187-073	unnamed tributary of Tate Creek	McDonald Road	Dahlonega	343636	835717	09/20/94	2.26
Lumpkin	187-074	unnamed tributary of Cane Creek	Wesley Lee Road	Campbell Mountain	343508	840108	09/27/94	1.01
Lumpkin	187-075	unnamed tributary of Moose Creek	Colonel Farrow Drive	Dahlonega	343729	835637	09/20/94	2.38
Lumpkin	187-076	unnamed tributary of Yahoola Creek	Junior Ward Road	Dahlonega	343432	835930	09/27/94	1.46
Lumpkin	187-077	Yahoola Creek	Yahoola Trace Road	Dahlonega	343657	835927	09/20/94	2.67

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COUNTY	SITE I.D.	STREAM NAME (if known)	ROAD INTERSECTION	QUADRANGLE	LATITUDE	LONGITUDE	DATE SAMPLED	NITRATE (N) - mg/l
Lumpkin	187-078	unnamed tributary of Yahoola Creek	Junior Ward Road	Dahlonega	343431	835916	09/27/94	1.22
Lumpkin	187-079	unnamed tributary of Yahoola Creek	Yahoola Church Road	Dahlonega	343715	835913	09/20/94	1.83
Lumpkin	187-080	Nimblewill Creek	Nimblewill Gap Road	Nimblewill	343459	840850	09/28/94	0.86
Lumpkin	187-081	unnamed tributary of Yahoola Creek	Martin Head Circle	Dahlonega	343433	835848	09/20/94	1.44
Lumpkin	187-082	unnamed tributary of Nimblewill Creek	Jess Grizzle Road	Nimblewill	343302	840734	09/28/94	1.3
Lumpkin	187-083	unnamed tributary of Yellow Creek	St. Paul Church Road	Murrayville	342648	835635	09/20/94	1.52
Lumpkin	187-084	Nimblewill Creek	Dan Grizzle Road	Nimblewill	343400	840746	09/28/94	0.91
Lumpkin	187-085	Etowah River	Jay Bridge Road	Campbell Mountain	343338	840426	09/28/94	0.93
Lumpkin	187-086	Mud Creek	Jay Bridge and Rider Mill Roads	Campbell Mountain	343317	840345	09/28/94	1.38
Lumpkin	187-087	unnamed tributary of Etowah River	Rider Mill Road	Campbell Mountain	343302	840344	09/28/94	1.34
Lumpkin	187-088	unnamed tributary of Clay Creek	Old Ellijay Road	Campbell Mountain	343203	840216	09/28/94	1.47
Lumpkin	187-089	unnamed tributary of Clay Creek	Clay Creek Falls Road	Campbell Mountain	343222	840134	09/28/94	1.72
Lumpkin	187-090	unnamed tributary of Ward Creek	County Road 35	Dahlonega	343344	835709	09/28/94	1.31
Lumpkin	187-091	unnamed tributary of Chestatee River	Leonard Pruitt Road	Dahlonega	343457	835601	09/28/94	1.64
Lumpkin	187-092	unnamed tributary of Chestatee River	Garnett School Road	Dahlonega	343431	835420	09/28/94	1.21
Lumpkin	187-093	unnamed tributary of Bull Creek	Major Abercrombie Road	Dahlonega	343047	835302	09/28/94	2.1
Lumpkin	187-094	unnamed tributary of Bull Creek	Georgia Highway 52	Clermont	342952	835145	10/03/94	2.6
Lumpkin	187-095	unnamed tributary of Bull Creek	Georgia Highway 52	Clermont	342939	835121	10/03/94	2.48
Lumpkin	187-096	unnamed tributary of Chestatee River	Leathers Ford Road	Murrayville	342607	835752	10/03/94	2.53
Lumpkin	187-097	unnamed tributary of Yellow Creek	Seven Mill Hill Road	Murrayville	342736	835706	10/03/94	3.14
Lumpkin	187-098	unnamed tributary of Bull Creek	Old Leathers Ford Road	Murrayville	342846	835505	10/03/94	2.33
Lumpkin	187-099	unnamed tributary of Long Branch	Red Oak Flats Road	Murrayville	342821	835709	10/03/94	2.28
Lumpkin	187-100	unnamed tributary of Yellow Creek	Floyd Sullens Road	Murrayville	342758	835628	10/03/94	2.23
Lumpkin	187-101	unnamed tributary of Yellow Creek	St. Paul Church Road	Murrayville	342715	835557	10/03/94	2.25
Lumpkin	187-102	unnamed tributary of Cavender Creek	Homer Edge Road	Dahlonega	343323	835444	10/03/94	3.46
Lumpkin	187-103	unnamed tributary of Frogtown Creek	U.S. Highway 19/129	Neels Gap	344307	835423	10/03/94	2.71
Lumpkin	187-104	unnamed tributary of Yahoola Creek	Yahoola Creek Farm Road	Dahlonega	343516	835831	10/04/94	1
Lumpkin	187-105	Lee Creek	Black Mountain Road	Suches	343812	840014	10/04/94	1.46
Lumpkin	187-106	Robison Creek	John Walden Road	Suches	343902	840010	10/04/94	1.96
Lumpkin	187-107	Walden Creek	Clayton Gooch Road	Suches	343851	840028	10/04/94	2.4
Lumpkin	187-108	Walnut Cove Creek	Jack Walker Road	Suches	343850	840024	10/04/94	1.64
Lumpkin	187-109	unnamed tributary of Yahoola Creek	Robinson Ridley Road	Dahlonega	343625	835910	10/04/94	1.54
Lumpkin	187-110	Ward Creek	Calhoun Road	Dahlonega	343437	835739	10/04/94	1.38
Lumpkin	187-111	Two Run Creek	Wahsega Road	Campbell Mountain	343710	840426	10/04/94	1.51
Lumpkin	187-112	unnamed tributary of Two Run Creek	Wahsega Road	Campbell Mountain	343715	840429	10/04/94	1.29
Lumpkin	187-113	unnamed tributary of Bull Creek	Miles Berry Road	Campbell Mountain	343536	840403	10/04/94	2.4
Lumpkin	187-114	Bull Creek	Bull Creek Road	Campbell Mountain	343625	840323	10/04/94	1.65
Lumpkin	187-115	Cane Creek	Johnnie Collins Road	Campbell Mountain	343404	840056	10/04/94	1.41
Lumpkin	187-116	unnamed tributary of Cane Creek	John W. Moore Road	Campbell Mountain	343335	840021	10/04/94	2.14
Lumpkin	187-117	unnamed tributary of Cane Creek	Cane Creek Falls Road	Campbell Mountain	343328	840022	10/04/94	1.64
Lumpkin	187-118	Clay Creek	Torrington Drive	Campbell Mountain	343156	840026	10/04/94	1.83
Morgan	211-001	Jacks Creek	Bostwick-High Shoals Road	High Shoals	334601	833040	09/14/94	0.78
Morgan	211-002	Little Sandy Creek	Jim Thomas Road	Rutledge North	333706	833204	10/05/94	0.8
Morgan	211-003	Apalachee River	Georgia Highway 186	High Shoals	334902	833021	09/14/94	0.27
Morgan	211-004	Jacks Creek	Price Mill Road	Watkinsville	334537	832927	09/14/94	0.89
Morgan	211-005	unnamed tributary of Jacks Creek	Georgia Highway 83	High Shoals	334503	833153	10/06/94	0.65
Morgan	211-006	Jacks Creek	Wagon Mill Road	Apalachee	334444	832745	09/22/94	0.79
Morgan	211-007	Beaverdam Creek	Price Mill Road	Apalachee	334257	832946	09/22/94	0.058
Morgan	211-008	Beaverdam Creek	Nolans Store Road	Apalachee	334237	832908	09/22/94	0.05
Morgan	211-009	Beaverdam Creek	Beaverdam Road	Apalachee	334121	832742	09/22/94	1.15
Morgan	211-010	Little Sandy Creek	Georgia Highway 83	Apalachee	334021	832952	09/19/94	1.06
Morgan	211-011	Hard Labor Creek	Georgia Highway 83	Apalachee	333814	832923	09/21/94	0.79
Morgan	211-012	Hard Labor Creek	U.S. Highway 129/441	Apalachee	333840	832653	09/26/94	0.65
Morgan	211-013	Big Sandy Creek	U.S. Highway 129/441	Apalachee	334002	832641	09/26/94	0.66
Morgan	211-014	Apalachee River	U.S. Highway 129/441	Apalachee	334307	832604	09/26/94	1.24
Morgan	211-015	Hard Labor Creek	Apalachee Road	Apalachee	333824	832353	09/26/94	0.85
Morgan	211-016	Big Sandy Creek	Sandy Creek Road	Apalachee	333931	832510	09/26/94	0.65
Morgan	211-017	Rocky Creek	Fairplay Road	Rutledge North	333917	833613	09/15/94	0.57
Morgan	211-018	Goose Creek	Apalachee River Road	Buckhead	333548	832126	09/26/94	0.74
Morgan	211-019	Goose Creek	Sugar Creek Church Road	Buckhead	333524	832204	09/26/94	0.62
Morgan	211-020	Sugar Creek	Mt. Zion Road	Buckhead	333109	831921	09/28/94	0.89
Morgan	211-021	Sugar Creek	Seven Island Road	Buckhead	333231	832136	09/28/94	0.85
Morgan	211-022	unnamed tributary of Little Sugar Creek	Kingston Road	Harmony	332930	832050	09/28/94	0.39
Morgan	211-023	Little Sugar Creek	Seven Island Road	Rock Eagle Lake	332955	832454	09/28/94	0.58
Morgan	211-024	Sugar Creek	Enterprise Road	Rock Eagle Lake	332923	832245	09/28/94	0.55
Morgan	211-025	Big Indian Creek	Seven Island Road	Rock Eagle Lake	332748	832823	09/23/94	0.94
Morgan	211-026	unnamed tributary of Big Indian Creek	Pierce Dairy Road	Rock Eagle Lake	332858	832722	09/23/94	1.02

APPENDIX C: LOW FLOW STREAM SAMPLING DATA

COUNTY	SITE I.D.	STREAM NAME (if known)	ROAD INTERSECTION	QUADRANGLE	LATITUDE	LONGITUDE	DATE SAMPLED	NITRATE (N) - mg/l
Morgan	211-027	Little River	Little River Road	Shady Dale	332704	833211	09/16/94	1.17
Morgan	211-028	Gap Creek	Little River Road	Shady Dale	332726	833342	09/16/94	1.84
Morgan	211-029	Gap Creek	Farrar Road	Shady Dale	332845	833422	09/16/94	0.37
Morgan	211-030	Gap Creek	Rocky Creek Road	Shady Dale	332848	833630	09/16/94	0.5
Morgan	211-031	Little River	Georgia Highway 83	Shady Dale	332908	833335	09/16/94	0.65
Morgan	211-032	Little River	Reese Road	Mansfield	333156	833800	09/20/94	0.74
Morgan	211-033	Shoal Creek	Newborn Road	Mansfield	333224	834018	09/20/94	0.99
Morgan	211-034	Hunnicutt Creek	Keencheefoonee Road	Mansfield	333321	833855	09/20/94	0.68
Morgan	211-035	Rocky Creek	Hawkins Academy Road	Social Circle	333826	833827	09/15/94	0.95
Morgan	211-036	Hard Labor Creek	Fairplay Road	Rutledge North	333956	833632	09/15/94	0.55
Morgan	211-037	Still Branch	Fairplay Road	Rutledge North	333902	833638	09/15/94	0.61
Morgan	211-038	Big Sandy Creek	Fairplay Road	Rutledge North	334258	833205	10/06/94	0.65
Morgan	211-039	Turkey Creek	Hardeman Mill Road	Rutledge North	334357	833306	09/19/94	1.32
Morgan	211-040	Little Sandy Creek	Hardeman Mill Road	Rutledge North	334335	833333	09/19/94	1.04
Morgan	211-041	Little Creek	Sandy Creek Road	Rutledge North	334119	833017	09/19/94	0.87
Morgan	211-042	Big Sandy Creek	Georgia Highway 83	Rutledge North	334143	833017	09/19/94	2.39
Morgan	211-043	Little Sandy Creek	Sandy Creek Road	Rutledge North	333943	833113	09/19/94	1.2
Morgan	211-044	Rawlings Branch	Newborn Road	Rutledge South	333629	833722	09/21/94	2.14
Morgan	211-045	Rawlings Branch	Fears Road	Rutledge South	333607	833557	09/21/94	1.27
Morgan	211-046	Rawlings Branch	Chilton Woods Road	Mansfield	333636	833735	09/21/94	2.01
Morgan	211-047	Little River	Clack Road	Rutledge South	333106	833523	09/21/94	1.23
Morgan	211-048	Big Indian Creek	Brownwood Road	Rutledge South	333403	833215	09/21/94	0.77
Morgan	211-049	Big Indian Creek	Clack Road	Rutledge South	333337	833133	09/21/94	0.92
Morgan	211-050	Halgers Creek	Wallace Grove Road	Rutledge South	333236	833711	09/20/94	0.62
Morgan	211-051	Big Indian Creek	Georgia Highway 83	Rutledge South	333131	833215	09/23/94	0.72
Morgan	211-052	Big Indian Creek	Indian Creek Road	Rutledge South	333017	833029	09/23/94	0.55
Morgan	211-053	Little Indian Creek	Georgia Highway 83	Rutledge South	333237	833036	09/23/94	0.67
Morgan	211-054	Speeds Branch	Georgia Highway 83	Madison	333713	832856	09/21/94	0.8
Morgan	211-055	Horse Branch	U.S. Highway 129/441 Bypass	Madison	333505	832645	09/27/94	1.02
Morgan	211-056	North Sugar Creek	Buckhead Road	Madison	333546	832530	09/27/94	0.86
Morgan	211-057	North Sugar Creek	Plainsview Road	Madison	333505	832503	09/27/94	1.19
Morgan	211-058	North Sugar Creek	Baldwin Dairy Road	Madison	333318	832331	09/27/94	1.48
Morgan	211-059	South Sugar Creek	Barrows Grove Road	Madison	333254	832359	09/27/94	0.63
Morgan	211-060	South Sugar Creek	Bethany Church Road	Madison	333245	832530	09/27/94	0.53
Morgan	211-061	Fourmile Branch	Indian Creek Road	Madison	333248	832933	09/23/94	1.06
Morgan	211-062	Little Indian Creek	Aqua Road	Madison	333057	832927	09/23/94	0.6
Morgan	211-063	Hard Labor Creek	Fambrough Bridge Road	Rutledge North	333813	833436	10/05/94	0.43
Morgan	211-064	Little River	Newborn Road	Mansfield	333322	834000	09/20/94	1.08
Morgan	211-065	Briar Creek	Briar Creek Road	Madison	333716	832239	09/26/94	0.59
Morgan	211-066	unnamed tributary of Little Sugar Creek	Porter Road	Madison	333048	832252	09/28/94	0.77
Morgan	211-067	unnamed tributary of Big Indian Creek	Pierce Dairy Road	Madison	333028	832821	09/23/94	0.95
Morgan	211-068	unnamed tributary of Little Sugar Creek	Kingston Road	Buckhead	333018	832017	09/28/94	0.45
Morgan	211-069	unnamed tributary of Sugar Creek	Cedar Grove Road	Buckhead	333207	832138	09/28/94	0.6
Morgan	211-070	unnamed tributary of Little Sugar Creek	Bethany Road	Buckhead	333103	832103	09/28/94	0.63
Morgan	211-071	Rawlings Branch	Centennial Road	Rutledge South	333601	833620	09/21/94	1.92
Morgan	211-072	Pole Ridge Creek	Weaver Jones Road	Rutledge South	333450	833529	09/21/94	0.93
Morgan	211-073	Pole Ridge Creek	Knight Road	Rutledge South	333302	833600	09/20/94	0.68
Morgan	211-074	unnamed tributary of Pole Ridge Creek	Knight Road	Rutledge South	333320	833524	09/20/94	0.82
Morgan	211-075	Big Indian Creek	Davis Academy Road	Rutledge South	333441	833307	09/22/94	0.083
Morgan	211-076	unnamed tributary of Big Indian Creek	Fears Road	Rutledge South	333442	833515	09/21/94	1.8
Morgan	211-077	Little Indian Creek	Indian Creek Road	Rutledge South	333124	833006	09/23/94	0.71
Morgan	211-078	Haglers Creek	Dickson Road	Rutledge South	333340	833730	10/05/94	0.51
Morgan	211-079	Haglers Creek	Centennial Road	Rutledge South	333509	833715	10/05/94	0.53
Morgan	211-080	Rice Creek	Centennial Road	Rutledge South	333657	833620	10/05/94	0.54
Morgan	211-081	Rice Creek	Newborn Road	Rutledge South	333706	833647	10/05/94	0.56
Morgan	211-082	Rice Creek	U.S. Highway 278	Rutledge South	333724	833721	10/05/94	0.51
Morgan	211-083	unnamed tributary of Rice Creek	U.S. Highway 278	Rutledge South	333722	833657	10/05/94	0.45
Morgan	211-084	unnamed tributary of Little Sugar Creek	Medlock Road	Harmony	332923	832245	09/28/94	0.52
Morgan	211-085	unnamed tributary of Little Sugar Creek	Paschal Road	Rock Eagle Lake	332908	832230	09/28/94	0.41
Morgan	211-086	Little Sugar Creek	Bethany Church Road	Rock Eagle Lake	332956	832508	09/27/94	0.71
Morgan	211-087	unnamed tributary of Little Sugar Creek	Bethany Church Road	Rock Eagle Lake	332923	832500	09/27/94	0.53
Morgan	211-088	Hunnicutt Creek	Interstate 20	Mansfield	333608	833929	09/27/94	1.33
Morgan	211-089	Hunnicutt Creek	Estes Road	Mansfield	333456	833909	09/20/94	1.12
Morgan	211-090	Hunnicutt Creek	Newborn Road	Mansfield	333438	833856	09/20/94	0.96
Morgan	211-091	Little River	Newborn Road	Mansfield	333500	833829	09/20/94	0.82
Morgan	211-092	Rawlings Branch	Old Mill Road	Mansfield	333656	833832	10/05/94	0.97
Morgan	211-093	unnamed tributary of Rawlings Branch	Old Mill Road	Mansfield	333712	833833	10/05/94	1.15

APPENDIX C: LOW FLOW STREAM SAMPLING DATA

COUNTY	SITE I.D.	STREAM NAME (if known)	ROAD INTERSECTION	QUADRANGLE	LATITUDE	LONGITUDE	DATE SAMPLED	NITRATE (N) - mg/l
Morgan	211-094	Big Sandy Creek	Sandy Creek Road	Rutledge North	334301	833335	10/05/94	0.66
Morgan	211-095	Hester Branch	Hester Town Road	Rutledge North	334208	833433	10/05/94	0.77
Morgan	211-096	unnamed tributary of Hard Labor Creek	Doster Road	Rutledge North	334014	833415	10/06/94	0.93
Morgan	211-097	unnamed tributary of Hard Labor Creek	Double Bridges Road	Rutledge North	333946	833427	10/06/94	0.82
Morgan	211-098	unnamed tributary of Hard Labor Creek	Double Bridges Road	Rutledge North	333917	833353	10/06/94	0.59
Morgan	211-099	Little Creek	Hester Town Road	Rutledge North	334110	833317	10/06/94	0.56
Morgan	211-100	unnamed tributary of Little Creek	Riden Road	Rutledge North	334154	833153	10/06/94	0.53
Morgan	211-101	unnamed tributary of Big Indian Creek	Brownwood Road	Rutledge South	333429	833145	10/18/94	1.51
Morgan	211-102	unnamed tributary of Big Indian Creek	Hillsman Road	Rutledge South	333109	833154	10/18/94	1.47
Morgan	211-103	unnamed tributary of Big Indian Creek	Spears Road	Rutledge South	333048	833208	10/18/94	1.7
Morgan	211-104	unnamed tributary of Big Indian Creek	Walker Road	Rutledge South	333013	833136	10/18/94	2.96
Morgan	211-105	Little River	Sewell Road	Mansfield	333426	834046	10/18/94	2.04

Appendix D

Nitrate in Georgia's Ground Water: Characterization of the Database and Preliminary Statistical Analysis

Earl A. Shapiro

INTRODUCTION

This document presents a large database on nitrate in the shallow ground water of Georgia. The size and geographic extent of the database suggest that it will be subject to future analysis as well as serve as the basis for future resource management and regulatory decisions. In order for such analysis and decisions to be technically sound, the database should be considered in a manner consistent with its statistical characteristics.

The database, hereinafter referred to as the "Nitrate Database", consists of three subsets: (1) a data set of nitrate concentrations in water from drinking water wells, hereinafter referred to as the "Water Well Subset"; (2) a data set of repeated samples from drinking water wells that show environmentally significant (> 5 mg/l of N) initial nitrate concentrations, hereinafter referred to as the "Resampled Well Subset"; and (3) a data set of nitrate in streams taken during low flow conditions in three counties, hereinafter referred to as the "Low Flow Subset".

The purpose of this Appendix is to statistically characterize the database and to perform some preliminary statistical analysis. The preliminary statistical analysis considers four issues: (1) geographic variation within the database; (2) temporal variation within the database; (3) inter-operator variation; and (4) comparability of the Low Flow Subset with the Water Well Subset. Preliminary manipulation of the database was performed using Quattro Pro for Windows, version 5.0. Statistical analysis was performed using SPSS for Windows, Release 6.0.

Although the present discussion primarily deals with the statistical characteristics of the Nitrate Database, it is important not to lose sight of EPD's primary objective in non-point source management. This is to be able to make a decision whether the current agricultural application of fertilizers and the disposal of human and animal waste are contributing levels of nitrates to shallow ground water at concentrations that endanger human health.

DATABASE CHARACTERIZATION

Sampling

Water Well Subset

Sampling for the Water Well Subset of the Nitrate Database was conducted by two different field teams, using different sampling strategies and different methodologies. The Georgia Southern field team, which concentrated their sampling within the Georgia Farm Belt, selected wells by driving through each county, looking for occupied houses that had wells and landowners that were agreeable to the sampling effort (Fredrick J. Rich, 1995, personal communication). They tried to distribute their sampling evenly throughout the Farm Belt counties. The Georgia Southern field team used Hach Company test kits to measure nitrate levels. The EPD field team used a self-selection methodology, with well owners responding to published articles. The EPD team concentrated its activities in north Georgia where human and animal waste disposal was considered to be the primary source of nitrates. The EPD field team used the Hach One ISE meter backed up by the Hach low-range nitrate test kit to measure nitrate levels.

Neither the "knocking on doors" sampling of the Georgia Southern team nor the self-selection sampling of the EPD team represent formal statistical random samples of either the unconfined aquifers or the shallow water wells of Georgia. Both sampling methodologies were constrained by EPD's policy of not entering onto private property without the knowledge and consent of the owner. The descriptions of the sampling methodologies, however, give no indication that the nitrate concentration of the wells directly affected either method of selection. Because well selection is independent of nitrate concentration, the Water Well Subset of the Nitrate Database may approximate a random sample of wells.

Resampled Well Subset

Initial samples in the Resampled Well Subset of the Nitrate Database were taken by either Georgia Southern or EPD. Therefore, the discussion of sampling for the Water Well Subset applies to the initial samples of the Resampled Well Subset. The EPD field team performed all resampling. Except for 30 wells that could not be retested (12.5% of high nitrate wells), all wells with nitrate concentrations above 5 mg/l were resampled. Therefore, the samples that make up the Resampled Well Subset approximate the population of high nitrate wells in the Water Well Subset. The original nitrate concentrations in the resampled wells were compared with the original nitrate concentrations in the 30 wells that could not be retested using the Kolmogorov-Smirnov two-sample test. There is no significant difference between the two groups of nitrate values (two-tailed probability = 0.477).

Low Flow Subset

The Low Flow Subset was sampled entirely by the EPD field team using a single methodology. Three counties were selected for low flow sampling: Barrow and Lumpkin counties, which are the two largest poultry producing counties in Georgia, and Morgan County, which is the largest milk producing county. EPD regards the investigation of these three counties as a "worst case" condition for nitrate pollution of streams. Stream sampling sites were selected on the basis of ease of access and even distribution throughout the three counties. All samples were collected over a 35 day period in September and October, 1994. The field team tried to distribute sampling sites evenly throughout the counties. Within the counties, there was no intentional bias toward placing sampling localities in proximity to either poultry or livestock production areas. Although the data do not constitute a formal random sample of streams in the tested counties, the data may approximate a random sample.

Frequency Distribution

Water Well Subset

Possible effects of geographic variation, temporal variation, inter-operator variation, and sample size were removed from the frequency distribution of the Water Well Subset by considering data only from single counties, with 30 or more samples, collected over a time interval of 365 days or less, by a single field team. Forty-one counties, out of 146 sampled, met these requirements (Figure D-1, p. D-5). The frequency distributions for these 41 counties were tested for normality using the Kolmogorov-Smirnov test. Six of those counties were randomly selected for purposes of illustration. Figure D-2 (p. D-6) shows that the frequency distributions of all six randomly selected counties are highly skewed to the right. The Kolmogorov-Smirnov test for normality indicates that the raw nitrate data from 39 of the 41 counties are significantly different from a normal distribution at the 0.05 probability level (note: in this Appendix, the term "significant" is frequently used in reference to the statistical analyses. In that context, the term "significant" refers only to probability levels and not to environmental significance. A data set may be statistically "significant" but environmentally non-significant, and vice versa.). The two non-significant results are what one would expect simply due to chance. Logarithmic and cube root transformations do not improve the normality of the data set. Therefore, because of the extreme skewness of the data, parametric statistical methods are not appropriate for examination of the Water Well Subset of the Nitrate Database.

Resampled Well Subset

The frequency distribution of the difference between the initial measurement of nitrate and the second measurement of nitrate is symmetric, but highly leptokurtic (peaked) relative to a normal distribution (Figure D-3, p. D-7). The frequency distribution is significantly different from a normal distribution (probability <0.0001 as indicated in Kolmogorov-Smirnov test for normality). The distribution has a mean of 3.5, a median of 4.3, a skewness of -0.57, and a kurtosis of 7.7 (for comparison a normal distribution has a skewness of 0.0 and a kurtosis of 1.0). The positive mean and median indicate that the initial nitrate concentrations were higher on average than the second measurements.

Low Flow Subset

The frequency distributions of the nitrate concentrations from streams sampled under low flow conditions differ significantly from a normal distribution (Figure D-4a, b, and c, p. D-8) (Kolmogorov-Smirnov test for normality; Barrow: probability = 0.0483, Lumpkin: probability = 0.0111, Morgan: probability < 0.0001). However, the frequency distributions of logarithmically transformed data from Barrow and Lumpkin counties (Figure D-4d and e) do not differ significantly from a normal distribution (Barrow: probability >0.2000, Lumpkin: probability >0.2000). Logarithmic transformation of the data from Morgan County (Figure D-4f) shows three data outliers at very low concentrations (0.05, 0.06, and 0.08 mg/l). These values are near the detection limits of the equipment used. When these three outliers are excluded from the data set, the Morgan County logarithmically transformed data are not significantly different from a normal distribution (probability = 0.1824). Therefore, the data in the Low Flow Subset for all three counties are distributed log-normally.

Sample Size

Water Well Subset

The sample size from each county in the Water Well Subset ranged from 5 to 69 samples, with a mean of 34.75 and a median of 33 samples. The sample size is not evenly distributed geographically. Counties in South Georgia, which are generally larger in area, tend to have more samples than counties in North Georgia. Counties in the eastern Coastal Plain tend to have the large sample sizes (these are the counties nearest to Georgia Southern University). Counties with the smallest sample sizes are either in proximity to urban centers (Atlanta, Augusta, Columbus, and Macon), where wells are generally not common, or in northwestern Georgia.

Resampled Well Subset

The Resampled Well Subset consists of two measurements per well. Initially 240 wells were recorded with nitrate values above 5 mg/l. Thirty of these wells could not be resampled. Of the remaining 210 wells, 21 are unsuitable for quantitative analysis because the nitrate values exceeded the upper detection limit of the analytical method used. This leaves 189 wells suitable for statistical analysis. For purposes of analysis, all measurements that are below the detection limit in the second sample are treated as zero.

The number of wells per county in the Resampled Well Subset ranges from one to nine wells. The mean number of resampled wells, suitable for statistical analysis, per county is two, with a median of two. Ninety-one counties contain resampled wells suitable for statistical analysis.

Low Flow Subset

The Low Flow Subset of the Nitrate Database consists of 124 measurements from Barrow County, 118 measurements from Lumpkin County, and 105 measurements from Morgan County. This is the largest, within-county set of measurements within the database.

GEOGRAPHIC VARIATION

Water Well Subset

Possible effects of inter-operator variation, temporal variation, and sample size, were removed from the Water Well Subset by restricting analysis to the 41 counties with 30 or more analyses, sampled by a single field team, within an interval of 365 days (Figure D-1). Thirty-nine of the 41 counties were sampled entirely by the Georgia Geologic Survey. Nonparametric analysis of variance (Kruskal-Wallis one-way analysis of variance) shows highly significant differences between counties (probability < 0.0001).

The effect of distance between counties was evaluated by comparing adjacent and distant counties. Three groups of adjacent counties (two in the Piedmont and one in the Coastal Plain) were selected (Figure D-5, p. D-9): Wilkinson and Twiggs counties (referred to as cluster one); Elbert, Franklin, Hart, and Madison counties (referred to as cluster two); Butts, Henry, Jasper, Morgan, Newton, Rockdale, and Walton counties (referred to as cluster three). Two groups of distant counties (one in the Piedmont and one in the Coastal Plain) were selected (Figure D-6, p. D-10): Hart, Warren, Upson, and Haralson counties (group one); and Berrien, Marion, and Wilkinson counties (group two). Because the selection of the groups of counties was non-random, the results of these comparisons must be considered as preliminary.

For the clusters of closely situated counties, there are no significant differences between counties in cluster one (Kolmogorov-Smirnov two-sample test, probability =0.088), or cluster three (Kruskal-Wallis one-way analysis of variance, probability = 0.2501); however, there are significant differences between counties within cluster two (Kruskal-Wallis one-way analysis of variance, probability = 0.0205). For the two groups of distant counties, there is a significant difference between counties in both group one (Kruskal-Wallis one-way analysis of variance, probability = 0.0051) and group two (Kruskal-Wallis one-way analysis of variance, probability <0.001).

Statistically significant differences in the nitrate concentration occur between counties, even after factors such as inter-operator variation and sampling interval are taken into account. These differences may be a function of the distance between counties.

Resampled Well Subset

Possible effects of inter-operator variation, temporal variation, and sample size, were removed from the Resampled Well Subset by considering only counties with three or more resampled wells, sampled by a single field team, within an interval of 365 days. Only two counties, Forsyth and Hart, met these restrictions. The nonparametric Mann-Whitney U-test shows that there are no significant differences between these two counties (probability = 0.8273).

The results from a comparison of two counties are not adequate to generalize about geographic variation within the 91 counties of the Resampled Well Subset. Considering that the Water Well Subset showed significant geographic variation, it is likely that significant geographic variation exists in the population of resampled wells.

Low Flow Subset

Because the Low Flow Subset is log-normally distributed, parametric analysis was performed. The Levene test for homogeneity of variances shows that there is no significant difference between variance in the three counties (probability = 0.135). This validates the use of a parametric analysis of variance (parametric analysis of variance assumes homogeneity of variances). One-way analysis of variance of the logarithmically transformed nitrate concentration data from the three counties, shows that there are highly significant differences between the counties (probability <0.0001). Post hoc multiple comparisons (Duncan Multiple Range and Scheffe tests) shows that all three counties differ from each other at the 0.05 probability level.

The statistical analysis shows that there are significant differences among the three counties in the nitrate concentrations measured in streams.

TEMPORAL VARIATION

The only data subset within the database that is adequate for considering temporal variation is the Resampled Well Subset. Within this data subset, each well was sampled twice with a resampling interval ranging from 38 to 1,284 days. Because each well is compared only with itself, the issue of geographic variation does not occur. Inter-operator variation is removed by considering only wells sampled by EPD. As noted in the discussion of the frequency distribution of the Resampled Well Subset, the original measurements of nitrate concentration are higher on average than the second measurements. A statistical comparison between the nitrate concentration in the original samples and in the second samples shows that the two sets of measurements are significantly different (Wilcoxon matched-pairs signed ranks test, probability < 0.0001).

INTER-OPERATOR VARIATION

Inter-operator variation is best examined by comparing the results of measurements taken by two operators on the same wells at the same time. The Water Well Subset of the database provides no opportunity for such comparisons. The Georgia Southern and EPD field teams worked in different counties during different years. Although the Resampled Well Subset of the database provides wells originally sampled by Georgia Southern field team and later resampled by EPD, the interval between the two sampling events is too large for direct comparison. A comparison of the difference between the two sampling events for wells originally sampled by Georgia Southern and those originally sampled by EPD would serve to test inter-operator variation, if the effects of geographic variation could be isolated. As previously discussed, the existing data do not allow for adequate isolation of geographic variation. In consequence, inter-operator variation cannot be examined with the present data set.

COMPARISON OF LOW FLOW SUBSET WITH WATER WELL SUBSET

This report points out that average nitrate concentrations in the stream samples were slightly higher than nitrate concentrations seen in wells for the three counties. A statistical comparison of the stream samples with water well samples from the three counties was performed using the nonparametric

Kolmogorov-Smirnov two-sample test. All three counties show highly significant differences between nitrate concentrations in the water well samples and the stream samples (two-tailed probability < 0.001).

CONCLUSIONS

Although the procedure used for selecting water wells in the Water Well Subset does not meet the formal requirements for random sampling, the subset does provide a general indication on nitrate concentrations in the shallow water wells of Georgia. The sample for the Resampled Well Subset consists of almost the entire population of high nitrate wells in the Water Well Subset. Therefore, conclusions reached from this subset apply to all high nitrate wells in the database.

The procedure used for selecting sampling points for the Low Flow Subset does not meet the formal requirements for random sampling, nevertheless the samples may approximate random samples. Because the counties were not selected in a formally random fashion, care must be used in projecting the results from these three counties to other counties in Georgia. The data in the Water Well Subset are skewed and do not approximate a normal distribution. The data cannot be transformed into a normal distribution. Because of this non-normality, the data must be treated by non-parametric statistical methods. Because of the skewness of the data, the mean is a poor measure of central tendency within the data set.

The data in the Resampled Well Subset are symmetrical, but are significantly different from a normal distribution. The use of nonparametric statistical methods is the safest approach to this data set. Because of the symmetric distribution of this data set, robust parametric tests may be used with some caution.

The data in the Low Flow Subset deviate significantly from normality, however, logarithmic transformation generally serves to normalize the data. Parametric statistics can be used on the transformed data.

Significant differences occur between counties in nitrate measurements from water wells (Water Well Subset). These differences may be a function of the distance between the counties. Distance may be a proxy for differences in hydrology, geology, precipitation, nitrate sources, agricultural practices, or other factors. The Resampled Well Subset is not adequate to test for differences between counties, however, because of the significant differences seen in the Water Well Subset, it is likely that significant geographic variation occurs in the resampled data. Significant differences between counties occur in the stream samples (Low Flow Subset).

Significant temporal variation is shown by the Resampled Well Subset. This indicates that care must be taken in comparing nitrate samples taken at different times.

The stream samples differ significantly from the water well samples taken from the same counties. This suggests that the two data sets are sampling different populations. However, because the samples from both data sets were not taken in a formal random manner, projection of these results to the unconfined aquifer and rivers of the three counties must be treated with caution.

Finally, this statistical analysis must be considered within the big picture of non-point source nitrate management. Georgia is a relatively large state and has a complex hydrogeology. The samples were collected by different teams, in different seasons, and in different years. Moreover, the sources of nitrate to shallow ground water are variable. Statistically significant differences between sampling subsets and counties are to be expected. However, when considering the data from the point of view of environmental significance, another picture emerges. Only those samples, where nitrate concentrations exceed 5 mg/l, were considered by EPD to be environmentally significant. Such concentrations occurred in 202 of the 5,072 samples wells and in none of the 347 low flow samples. Only 49 wells had nitrate concentrations exceeding the MCL of 10 mg/l; and as discussed in the main body of the text, obvious nitrate sources could be identified in the immediate vicinity of these wells. Therefore, even though statistical differences could be identified within and between data base subsets, the data clearly indicate that non-point source nitrate pollution of shallow ground water is not environmentally significant.

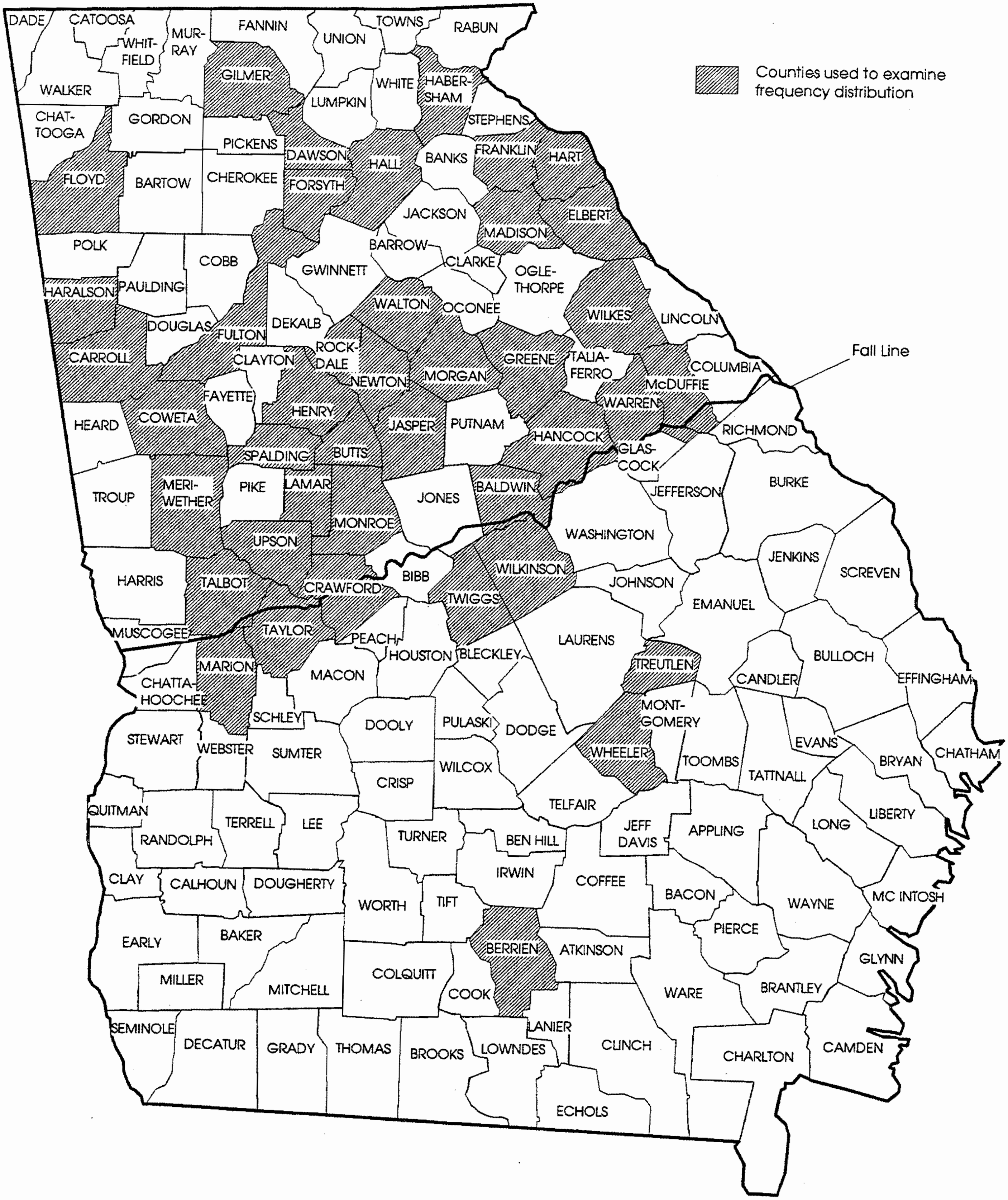


Figure D-1. Forty-one counties in the Water Well Subset with 30 or more samples, collected within 365 days, by a single field team.

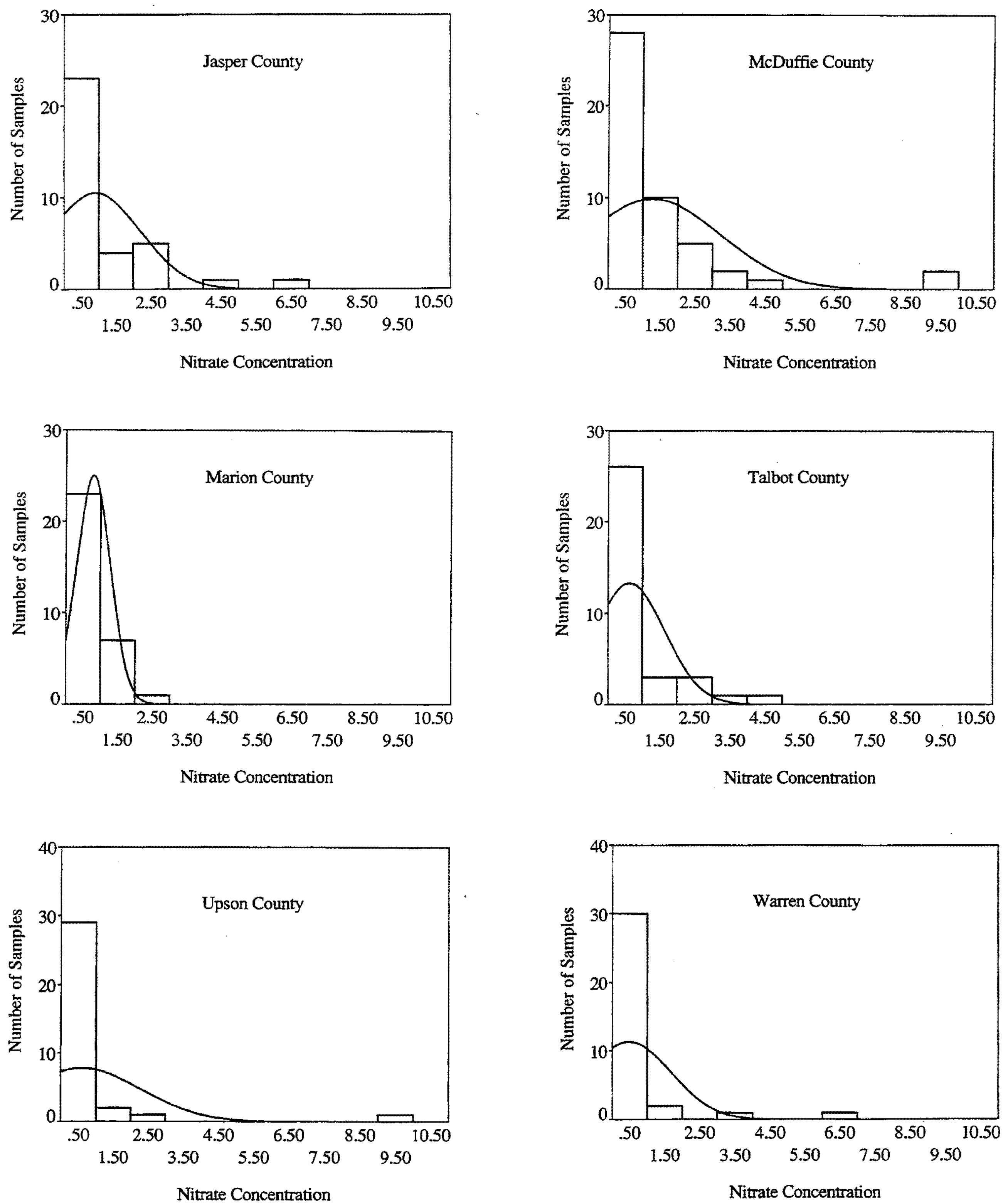


Figure D-2. Frequency distributions of Water Well Subset in six counties. Counties selected randomly from 41-county subset. The smooth curve superimposed on each histogram is a normal distribution centered on the county mean value.

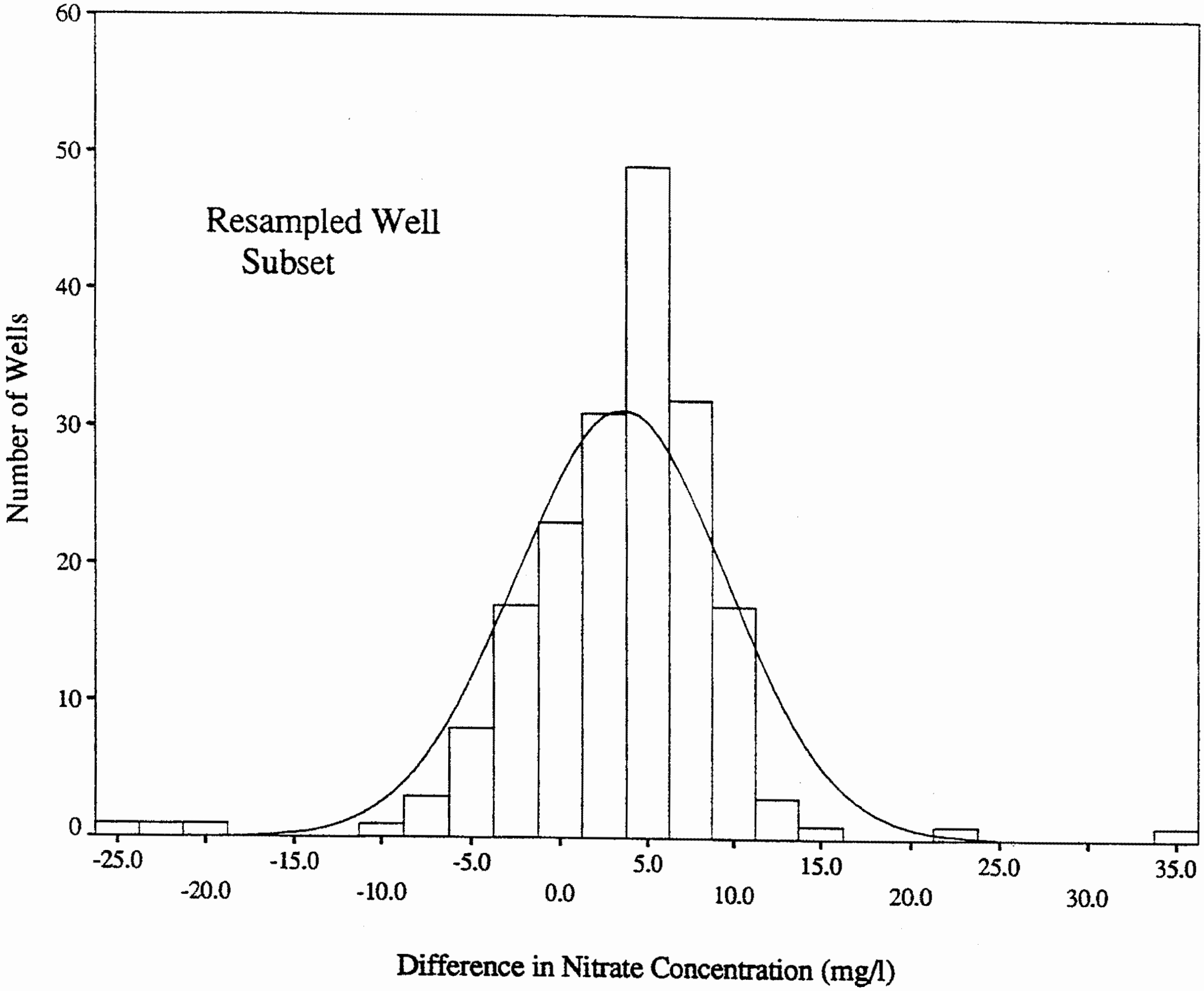


Figure D-3. Frequency distribution of the Resampled Well Subset. The smooth curve superimposed on the histogram for comparison is a normal distribution centered on the population mean.

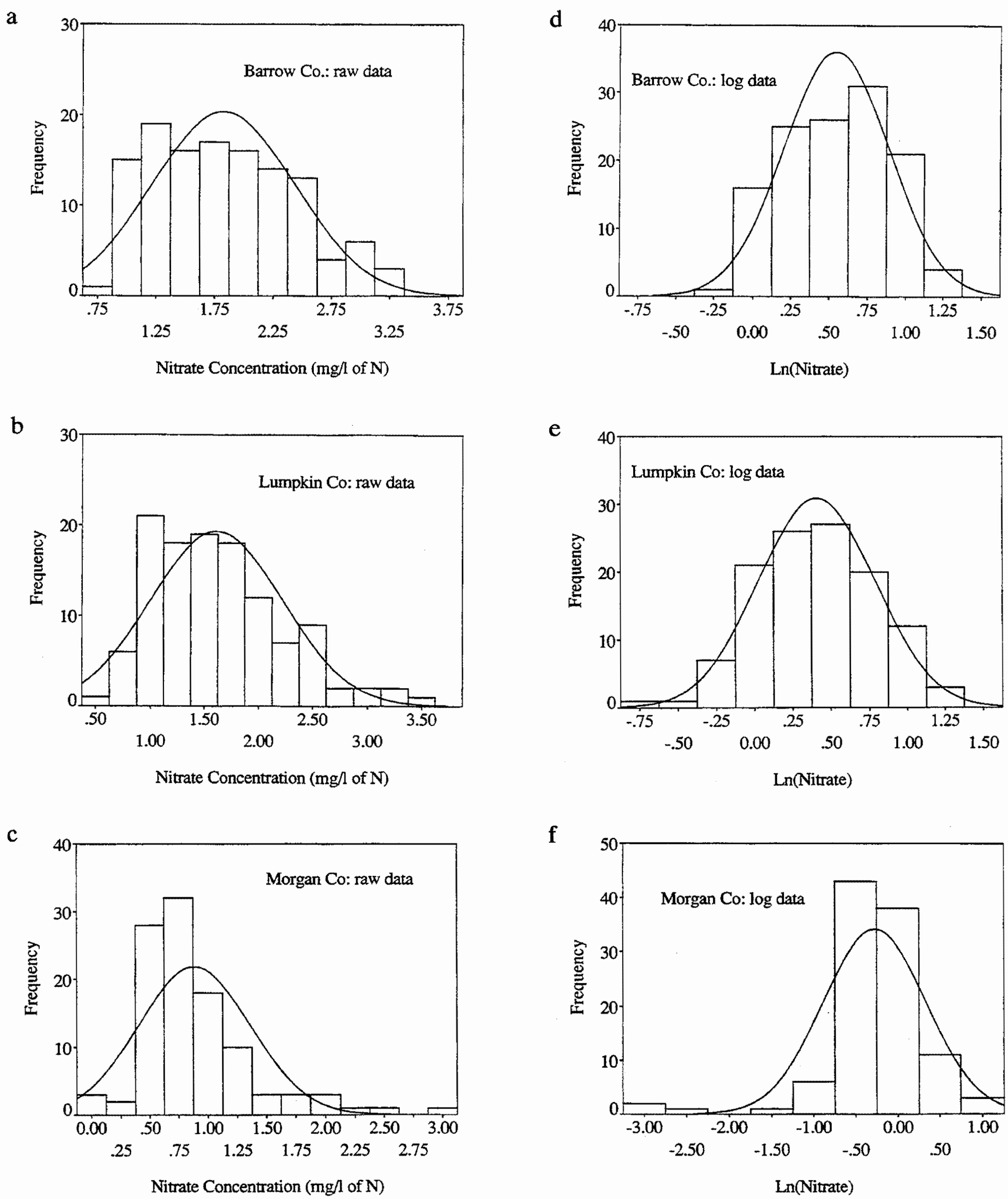


Figure D-4. Frequency distributions of Low Flow Subset. The smooth curve superimposed on each histogram is a normal distribution centered on the county mean value. 4a, 4b, and 4c show the distributions of the raw data. 4d, 4e, and 4f show the distributions of the logarithmically transformed data.

Figure D-5. Three groups of adjacent counties.

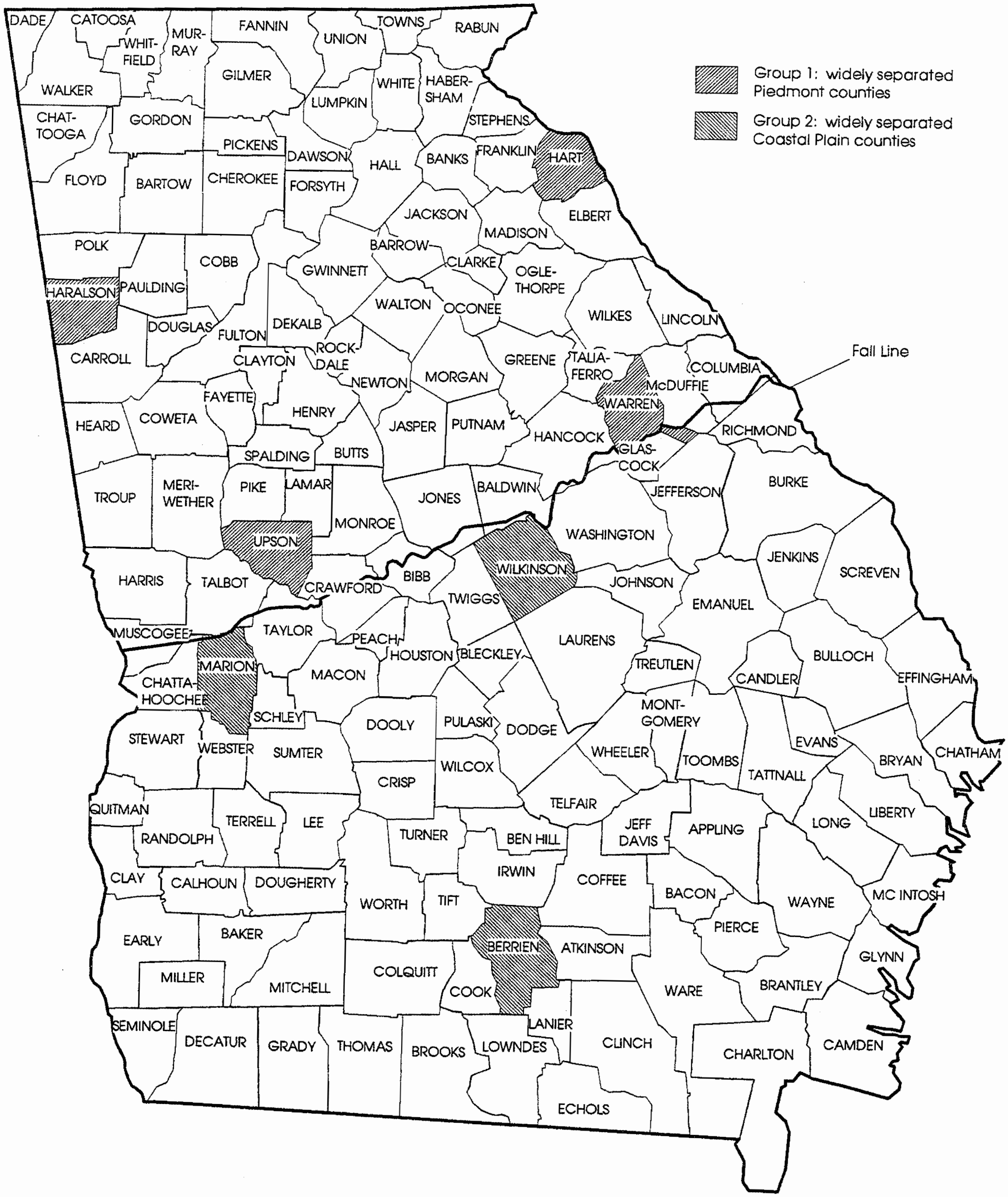
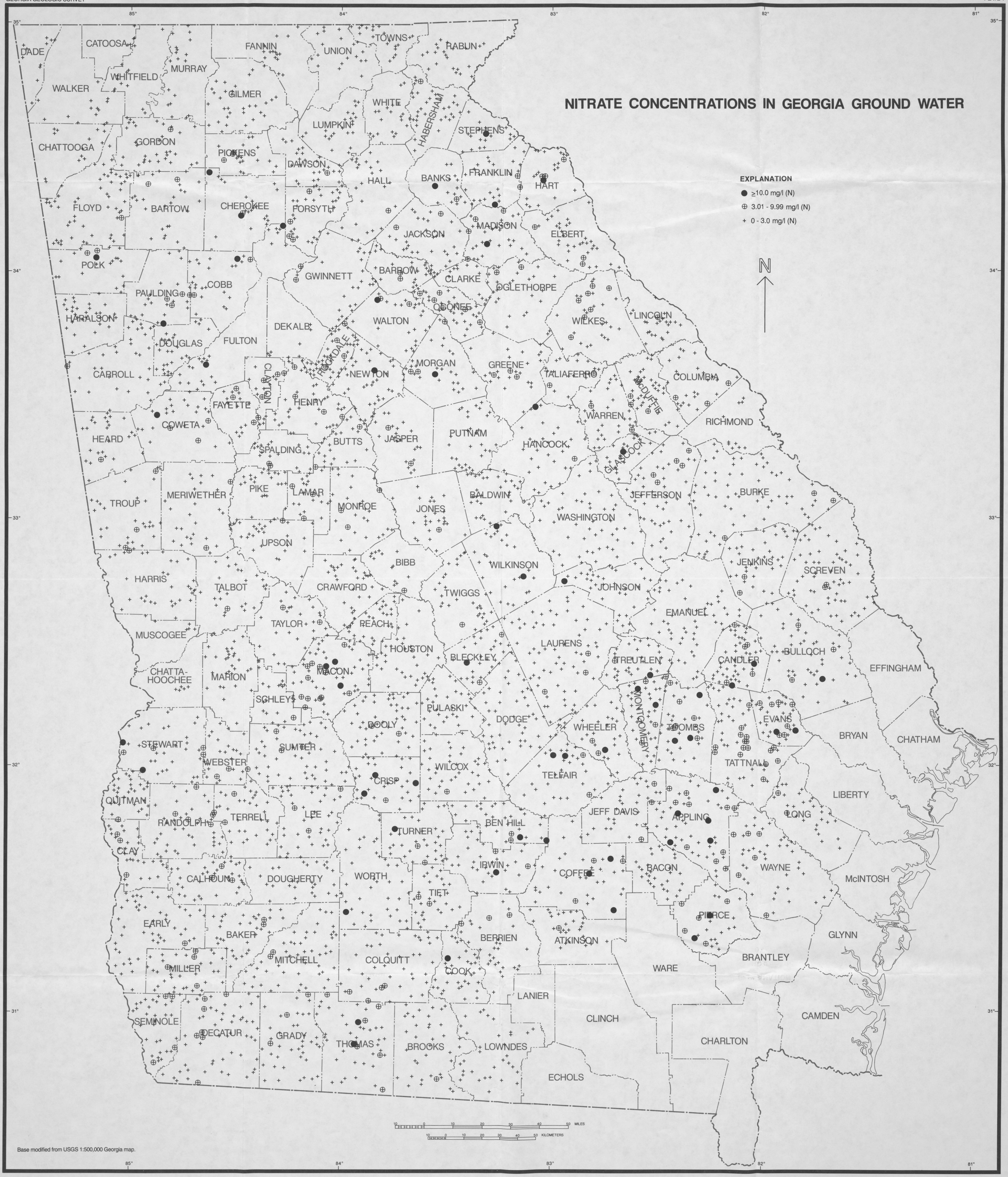


Figure D-6. Two groups of distant counties.

NITRATE CONCENTRATIONS IN GEORGIA GROUND WATER



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