Pesticide concentrations at all fixed sites ranged from 0.001 to 2.0 µg/L (table 4). Ten pesticides—atrazine, bromacil, dichlorprop, 2,6-diethylaniline, metolachlor, metribuzin, simazine, carbaryl, carbofuran, and diazinon—were detected in water samples at concentrations greater than 0.10 µg/L (table 4). In 47 of the 362 water samples collected at the fixed sites, one or more pesticides were detected at a concentration greater than 0.10 µg/L. Concentrations of atrazine exceeded 0.10 µg/L in 37 samples, and concentrations of metolachlor exceeded 0.10 µg/L in 11 samples. Seven water samples had concentrations of one or more pesticides exceeding 0.50 µg/L, and only four samples had concentrations of one or more pesticides that exceeded 1.0 µg/L.

Differences in pesticide occurrence among the three agricultural sites (Big Limestone Creek, Copper Creek, and Nolichucky River) were related to the variety of land uses and pesticide application within each basin. Among the agricultural sites, more pesticides (22) were detected in samples from the Nolichucky River near Lowland than from the other agricultural sites (fig. 4). Similarly, more pesticides also were detected in samples from Big Limestone Creek (17) than at Copper Creek (11) probably because of a greater percentage of agricultural land use and a greater variety of crops grown in the Big Limestone Creek Basin. Tebuthiuron, a noncropland herbicide often applied to powerline and road rights-of-way, was detected at a substantially higher frequency at Copper Creek than at the Nolichucky River or Big Limestone Creek. Detection frequencies for Big Limestone Creek and the Nolichucky River near Lowland were similar for atrazine, deethylatrazine, metolachlor, napropamide, and carbofuran (fig. 4). The most noticeable difference between these two sites was that metribuzin, an herbicide used to control a large number of grasses and broadleaf weeds on a variety of agricultural crops (potatoes, soybeans, and winter wheat), was detected in 17 percent of the samples at the Nolichucky River near Lowland but was not detected at Big Limestone Creek. Big Limestone Creek is a tributary to the Nolichucky River, and both drain the same general agriculturally dominated area; however, the Big Limestone Creek Basin contains a higher percentage of agricultural land use (both pasture and cropland) than the remainder of the Nolichucky River Basin. Agricultural land accounts for only about 39 percent (650 mi^2) of the drainage upstream of the Nolichucky River site; however, most of the area adjacent to or directly upstream from the sampling site is predominantly agricultural.

Detection frequencies of pesticides at the three agricultural sites generally characterize pesticide detection at all fixed sites; however, some noticeable differences were observed (fig. 4). At the agricultural

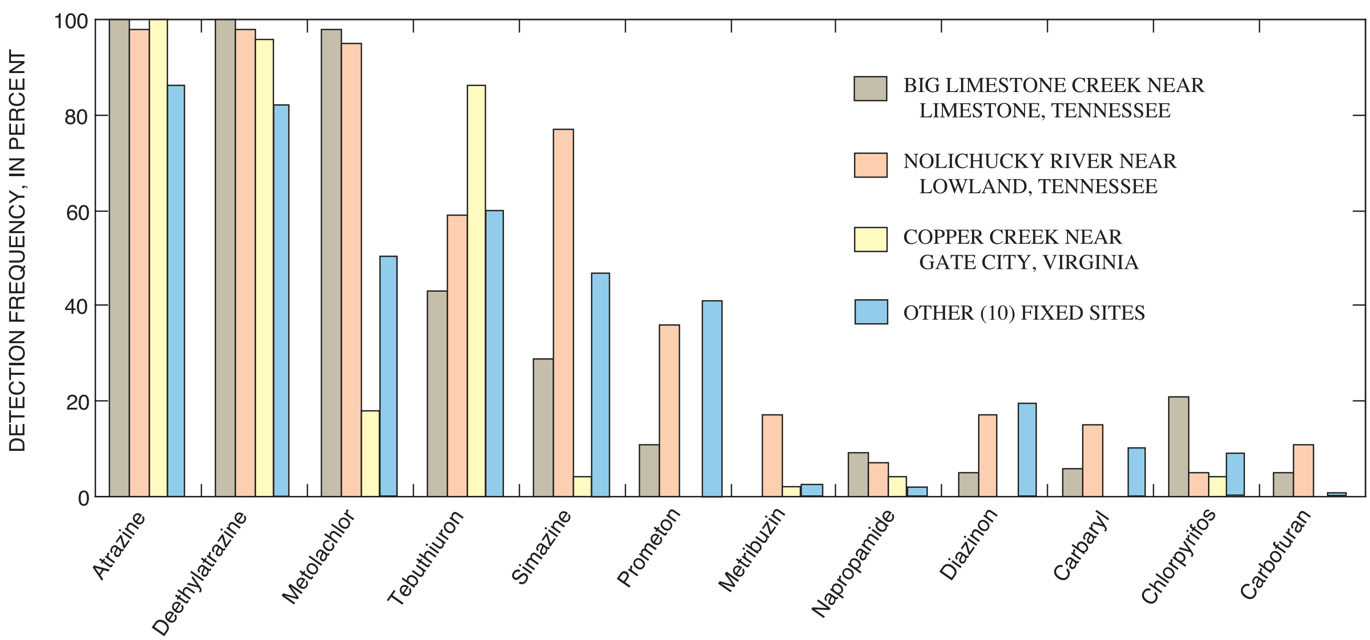

Figure 4. Pesticide detection frequency for the agricultural sites compared with the other fixed sites in the upper Tennessee River Basin.

sites, 27 different pesticides were detected. Detection frequencies at Big Limestone Creek near Limestone and the Nolichucky River near Lowland were particularly high when compared to the detection frequencies at the other fixed sites for the pesticides (atrazine and metolachlor), which are commonly used for agriculture in the UTEN. Detection frequencies of pesticides in water samples at the Nolichucky River site more closely resembled detection frequencies at the other 10 fixed sites probably because of a greater degree of mixed land use in the Nolichucky River Basin. Detection frequencies of pesticides for Copper Creek, however, varied considerably from the other sites, particularly for some of the more commonly detected pesticides such as metolachlor, simazine, and prometon (fig. 4). Tebuthiuron was detected more frequently at Copper Creek than at the other agricultural sites, perhaps as a result of road construction and weed control on roadway rights-of-way upstream of the sampling site. At Copper Creek, 11 pesticides were detected in 51 samples; however, only 4 pesticides were detected in more than 2 samples (less than 4 percent of samples).

Of the 47 pesticides that were analyzed in all samples (using the GC/MS method), 7 pesticides detected at the fixed sites were not detected at any of the sites included in the spatial analysis. Conversely, only one pesticide (terbacil) was detected at a spatial-analysis site that was not detected in samples collected at the fixed sites.

Comparisons of Detection Frequencies in the Upper Tennessee River Basin with Detection Frequencies Across the Nation

Pesticide detection frequencies for the UTEN were compared to a national summary of pesticide detections compiled by the USGS from NAWQA studies that were completed in 36 of the Nation's major hydrologic basins from 1992 to 1998 and that included analyses of about 2,500 samples collected at 115 fixed sites. Pesticide detection frequencies in the UTEN were compared to the national averages for stream sites with agricultural drainages as well as for sites with drainages of mixed land use.

Atrazine, deethylatrazine, tebuthiuron, and napropamide were detected in streams of agricultural drainages in the UTEN more frequently than at agricultural sites included in the national summary of pesticide detections (fig. 5). Atrazine and deethylatrazine were detected in 99 and 98 percent of samples in the UTEN compared to the national average for agricultural sites of 85 and 69 percent, respectively. Tebuthiuron was detected in 62 percent of samples in the UTEN compared to the average of 22 percent for agricultural sites nationwide. The detection frequency for napropamide in the UTEN slightly exceeded the national average for agricultural indicator sites (6.2 and 5.6 percent, respectively). Pesticides that were detected considerably less frequently in the UTEN streams than at the nationwide agricultural sites

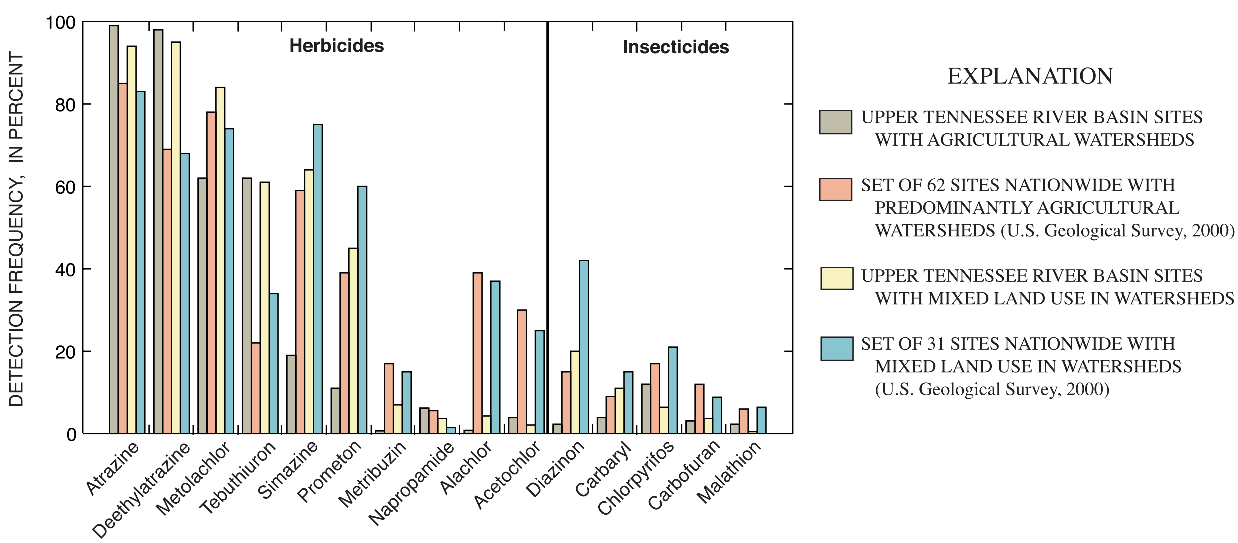

Figure 5. Pesticide detection frequencies in the upper Tennessee River Basin compared with national averages from previous National Water-Quality Assessment Program investigations across the Nation.

included alachlor, acetochlor, carbofuran, diazinon, metolachlor, metribuzin, prometon, and simazine.

Atrazine, deethylatrazine, metolachlor, tebuthiuron, and napropamide were detected more frequently at mixed land-use sites in the UTEN than at mixed land-use sites included in the national summary of pesticide detections (fig. 5). Atrazine and deethylatrazine were detected in 94 and 95 percent of samples from mixed land-use sites in the UTEN compared to the national average for mixed land-use sites of 83 and 68 percent, respectively. For mixed land-use sites, metolachlor was detected in 84 percent of samples in the UTEN compared to 74 percent nationwide; and tebuthiuron was detected in 61 percent of samples in the UTEN compared to the average of 34 percent for mixed land-use sites nationwide. Detection frequency for napropamide in the UTEN slightly exceeded the national average for mixed land-use sites (fig. 5). Comparison of detection frequencies at sites with mixed land-use drainages in the UTEN with national averages reveal results similar to the agricultural sites with the exception of metolachlor, which was detected more frequently in the UTEN.

Water-Quality Standards

The U.S. EPA has established water-quality standards and guidelines that specify thresholds of concentrations of certain chemicals that have adverse effects on human health, aquatic organisms, and wildlife. Although the maximum contaminant levels (MCL) and lifetime health advisory levels (HAL) established by the U.S. EPA (2000) pertain to finished drinking water supplied by a community water system, values are provided with which ambient concentrations can be compared. MCLs or HALs have been established for 21 of the 31 pesticides and metabolites detected at sites in the UTEN study (table 4). Aquatic-life criteria have been established for the protection of aquatic organisms for short-term (acute) and long-term (chronic) exposures. Chronic aquatic-life criteria have been established for 14 of the 31 pesticides and metabolites detected at sites in the UTEN study (table 4).

Concentrations of pesticides and metabolites detected in streams in the UTEN generally were below established water-quality standards and guidelines. Although most of the samples collected in the UTEN contained detectable concentrations of one or more pesticides, no concentrations exceeded any human health standards (MCLs or HALs). Only 2 percent of the samples collected at UTEN sites had concentrations of one or more pesticides that exceeded the chronic aquatic-life criteria (fig. 6), and the exceedances were for atrazine, diazinon, carbaryl, and lindane.

Total pesticide concentrations were computed by summing the concentrations of the detectable pesticides (above the MRL) for each sample in order to account for the presence of multiple pesticides. Total pesticide concentrations for samples collected at the fixed sites in the UTEN ranged from less than 0.001 μg/L at Clear Creek at Lilly Bridge near Lancing, Tenn., to 3.15 μg/L for a sample with eight pesticide detections collected at Nolichucky River near Lowland, Tenn. The effects of pesticide mixtures on biota and human health are unknown; however, this is an area of active research, and the U.S. EPA is considering establishing health standards for combinations of pesticides (U.S. Environmental Protection Agency, 1994).

SEASONAL AND SPATIAL VARIABILITY OF PESTICIDES IN STREAMS OF THE UPPER TENNESSEE RIVER BASIN

Pesticide occurrence and concentrations varied seasonally and spatially in the UTEN and were closely associated with land use and time of application. Peak concentrations of pesticides generally were detected during the spring and immediately following pesticide application. However, low levels (concentrations generally less than 0.10 μg/L) of pesticides were detected throughout the year at the fixed sites in the UTEN.

Seasonal variability was evident for several pesticides at the 13 fixed sites. Monthly sampling for pesticides at fixed sites was conducted to characterize the seasonal variation of pesticides in streams in the UTEN. Peak concentrations occurred during the growing season (April through September) for all pesticides except dichlobenil, trifluralin, and *alpha* HCH (table 4). Differences in pesticide concentrations (and detection frequencies) between the growing and nongrowing seasons were pronounced for the French Broad River, Middle Fork Holston River, Clinch River, Clear Creek, Big Limestone Creek, and Nolichucky River. Although comparisons of median concentrations between the growing and nongrowing seasons indicate little change for some sites (Guest River and Copper Creek), maximum concentrations for most pesticides were detected during the growing

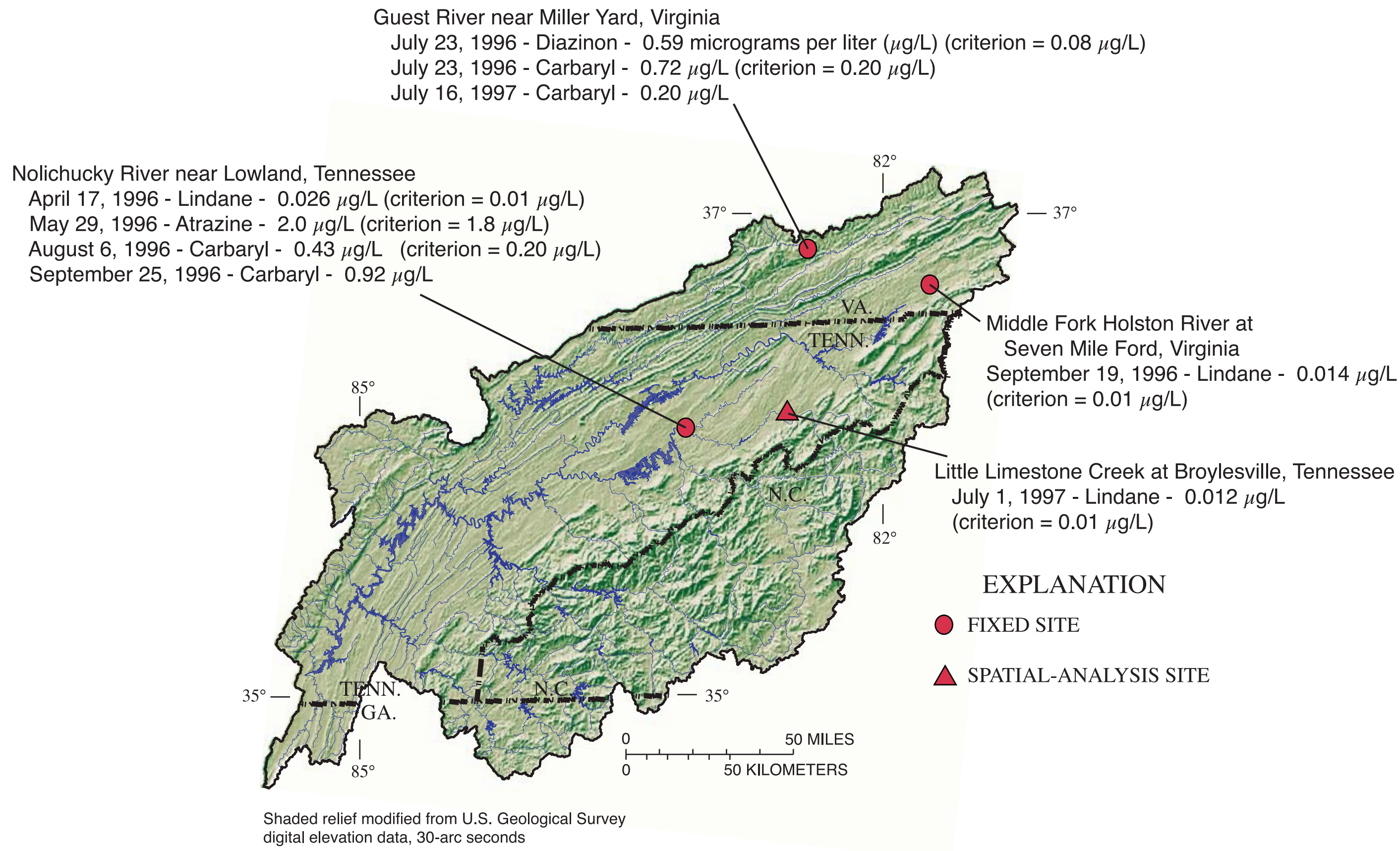

Figure 6. Location of stream sites with samples in which pesticide concentrations were equal to or exceeded aquatic-life criteria in the upper Tennessee River Basin.

season, usually during June and July following the application of agricultural pesticides, at all fixed sites (table 4). Elevated concentrations of several pesticides including atrazine, deethylatrazine, metolachlor, tebuthiuron, simazine, prometon, and chlorpyrifos were detected during the growing season at most fixed sites.

Weekly sampling at the three agricultural sites, where the upstream drainage areas contained large percentages of agricultural land, revealed that the highest pesticide concentrations were detected in late spring and early summer (fig. 7). Peak herbicide concentrations usually coincided with the first substantial storm following agricultural applications in the spring and declined to near-background levels as concentrations were diluted by the increased discharge that accompanied the storm. Maximum concentrations of herbicides were detected during May and June following the application of herbicides to farm fields and residential lawns. Of the 39 samples that contained at least one pesticide with a concentration greater than 0.1 µg/L at the three agricultural sites, 36 samples were collected during the months of May, June, July, and August.

Data were collected at 61 stream sites to analyze the spatial variation of pesticides in 7 major subbasins and 3 smaller tributaries to the Tennessee River (fig. 2). Sampling conducted during the late springs and early summers of 1996, 1997, and 1998 was focused on low streamflow conditions in agricultural and mixed land-use settings. A few water samples were collected in urban streams that are influenced by industrial and municipal effluents and urban runoff. In 1996, data collection was focused in the Clinch, Powell, and Emory River Basins; in 1997, in the Nolichucky and French Broad River Basins, and in 1998, in the Holston River Basin. Because of breaks in the sampling schedule as a result of unsuitable hydrologic conditions, these data do not portray nearly instantaneous, concurrent water-quality conditions, as would have been possible if intensive sampling had been performed over a short time period. Instead, greater emphasis was given to sampling under consistent streamflow conditions. Because of the offsets in

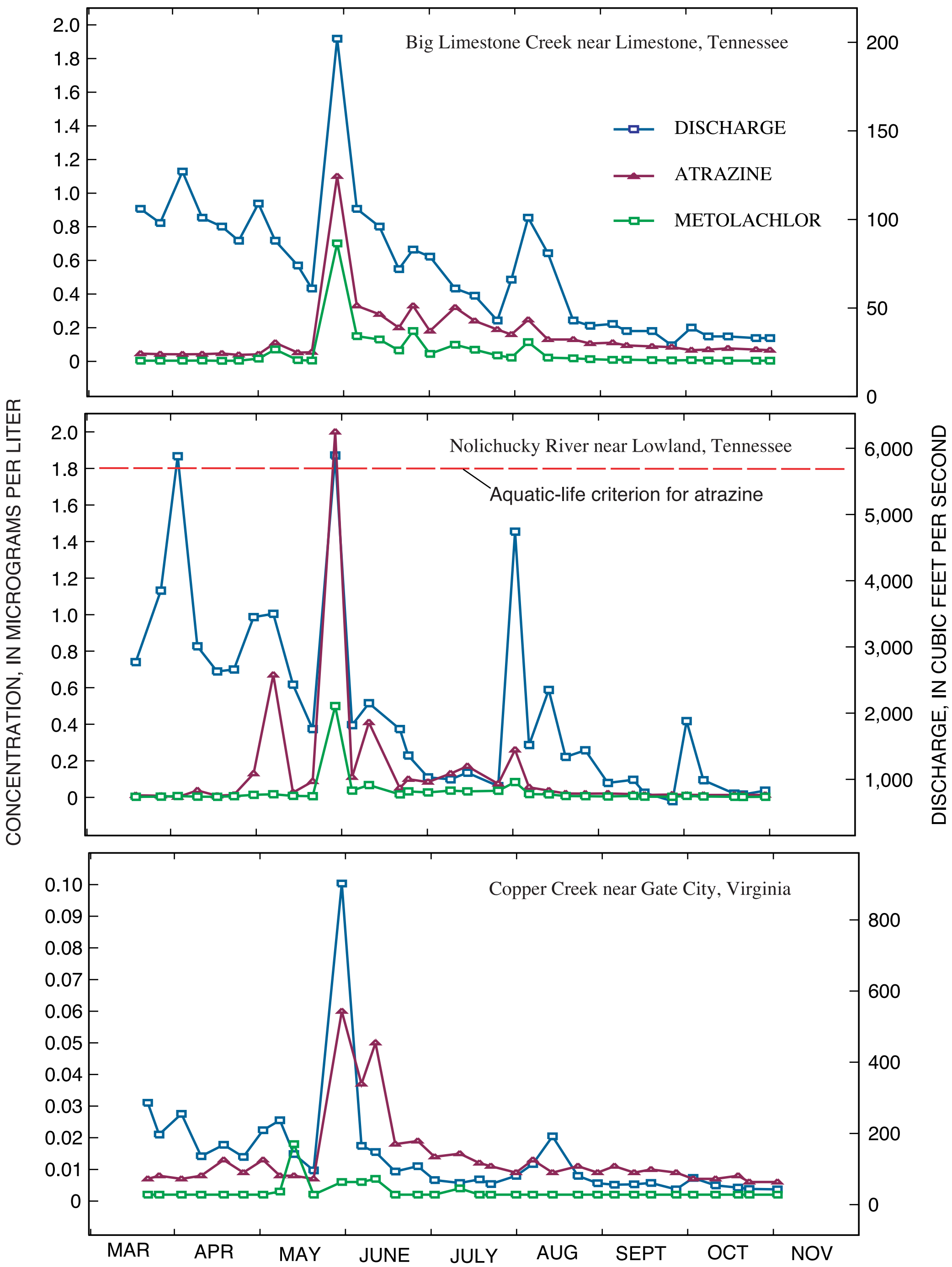

Figure 7. Seasonal variation in pesticide concentrations at agricultural sites in the upper Tennessee River Basin, 1996.

sampling dates, potential for variations of pesticide concentrations exists among sites; therefore, these variations of concentrations can be related to variation in timing of sampling relative to pesticide applications.

In 1996, sampling was conducted at 24 sites primarily in the Clinch, Powell, and Emory River Basins to evaluate spatial distribution of pesticides. Twelve pesticides were detected at sites in the Clinch and Powell River Basins; the number of pesticides detected per sample ranged from one to eight (fig. 8). Atrazine was detected most frequently (100 percent) in samples from the Clinch River Basin sites, and tebuthiuron was detected most frequently (100 percent) in samples from the Powell River Basin sites. Concentrations of all detected pesticides were relatively low (less than 0.10 µg/L), with the exception of two tebuthiuron concentrations (0.21 and 0.26 µg/L) in samples from the Powell River Basin.

The spatial-analysis sites sampled in the Emory River Basin are located within the Obed National Wild and Scenic River system. Two or three pesticides were detected at each of the five sites sampled in the Emory River Basin in 1996 (fig. 9). Six pesticides were detected at one additional site that was sampled in 1998. Atrazine and deethylatrazine were detected in all samples, and prometon was detected in half of the samples. Metolachlor and tebuthiuron were detected in two samples, and diazinon was detected in one sample. Concentrations of the detected pesticides were generally less than 0.10 µg/L.

The French Broad River Basin sites were sampled in the spring and summer of 1997. Sampling began in April but was discontinued for several weeks because of extremely wet weather and high streamflow conditions; sampling resumed in June and was completed in July. Concentrations for 14 different pesticides—8 herbicides, 5 insecticides, and 1 metabolite—were detected at 20 fixed and spatial-analysis

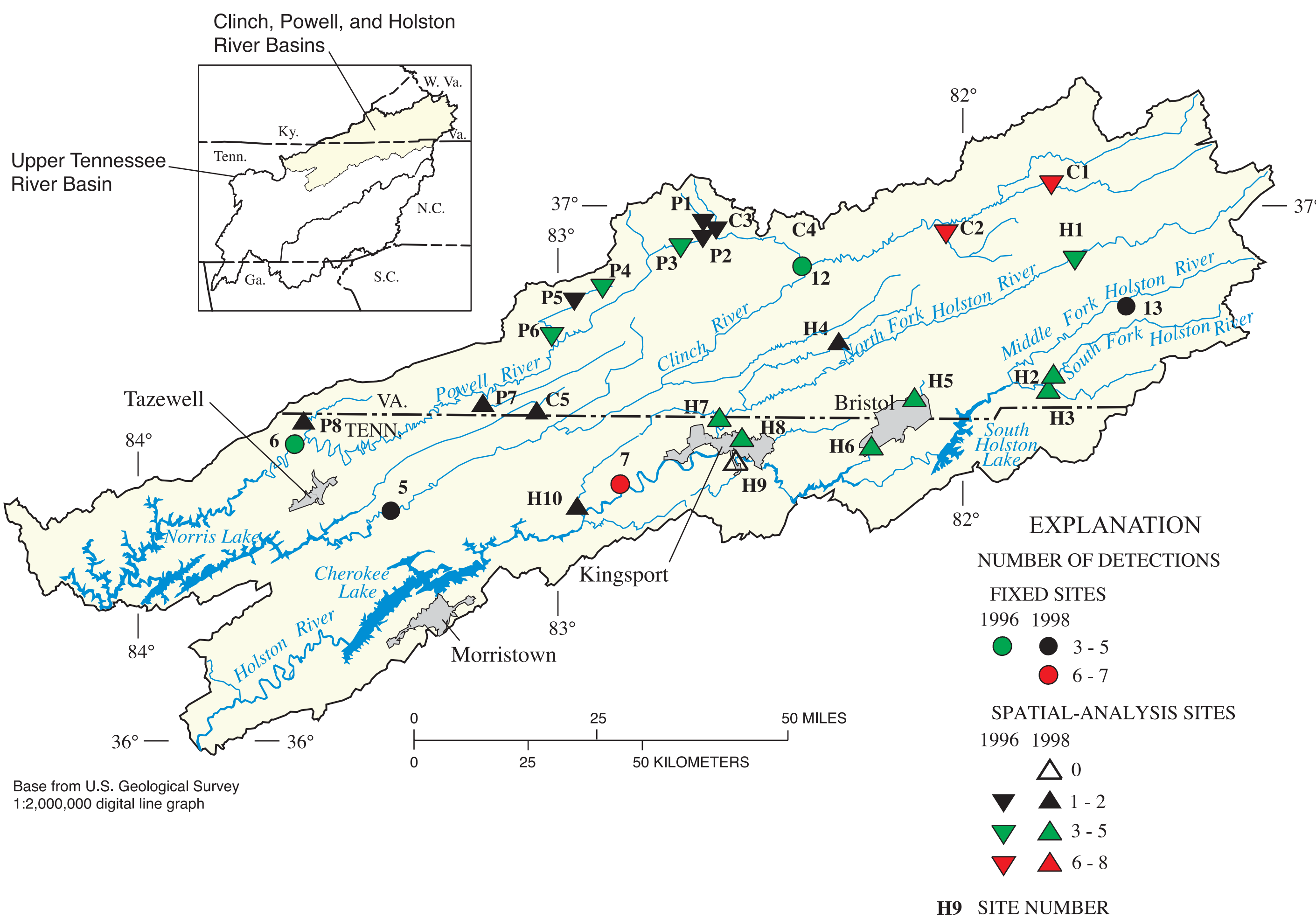

Figure 8. Pesticides detected in samples collected at low flow from 28 stream sites in the Clinch, Powell, and Holston River Basins, 1996 and 1998.

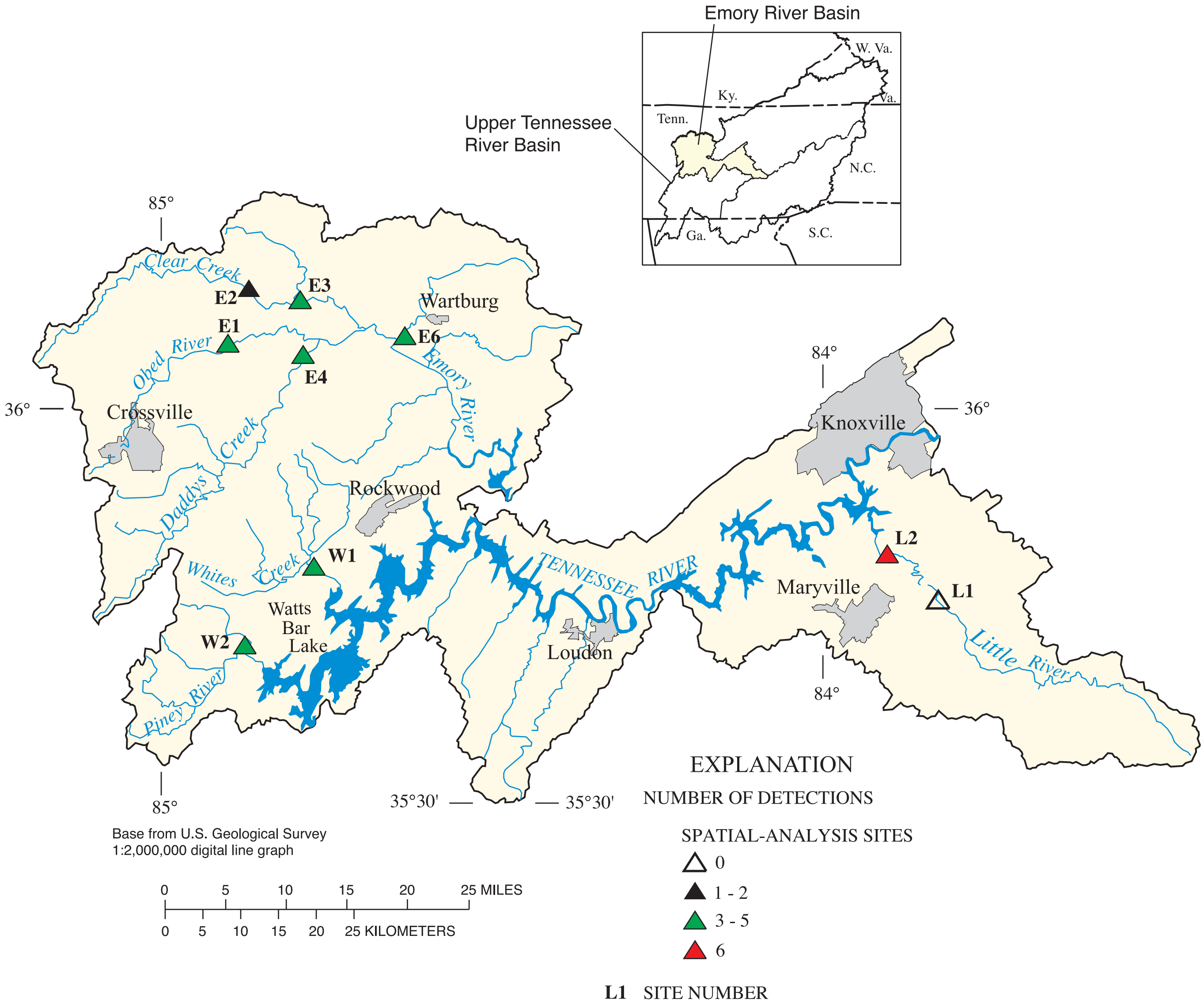

Figure 9. Pesticides detected in samples collected at low flow from 9 stream sites in the Emory River Basin and other tributaries to the upper Tennessee River, 1996.

sampling sites. The number of pesticide detections per sample ranged from none detected at five sites to eight pesticides detected at three sites (fig. 10). The largest number of detections were from samples in the urban drainages of the Asheville, N.C., area. The only detection of the herbicide terbacil was at Mud Creek (F5 on fig. 10 and appendix A), which is an urban stream near Asheville that is influenced by industrial activity. Pesticide concentrations were generally lower in the French Broad River Basin than in the other study-unit basins with the exception of prometon, which was detected at a concentration of 0.16 µg/L in the French Broad River at Glenn Bridge Road near Arden, N.C. (F7 on fig. 10 and appendix A).

Nolichucky River Basin sites also were sampled in the summer of 1997. Concentrations for 15 different pesticides—10 herbicides, 4 insecticides, and 1 metabolite—were detected at 10 fixed and spatial-analysis sampling sites. The number of pesticides detected per site ranged from four to nine. The three fixed sites in the basin, Nolichucky River near Lowland, Tenn. (site 4), Nolichucky River at Embreeville, Tenn. (site 10), and Big Limestone Creek near Limestone, Tenn. (site 9), were sampled during the same time period as the spatial-analysis sites. Nine pesticides were detected at the Nolichucky River near Lowland, six pesticides were detected at the Nolichucky River at Embreeville, and five pesticides were detected at Big

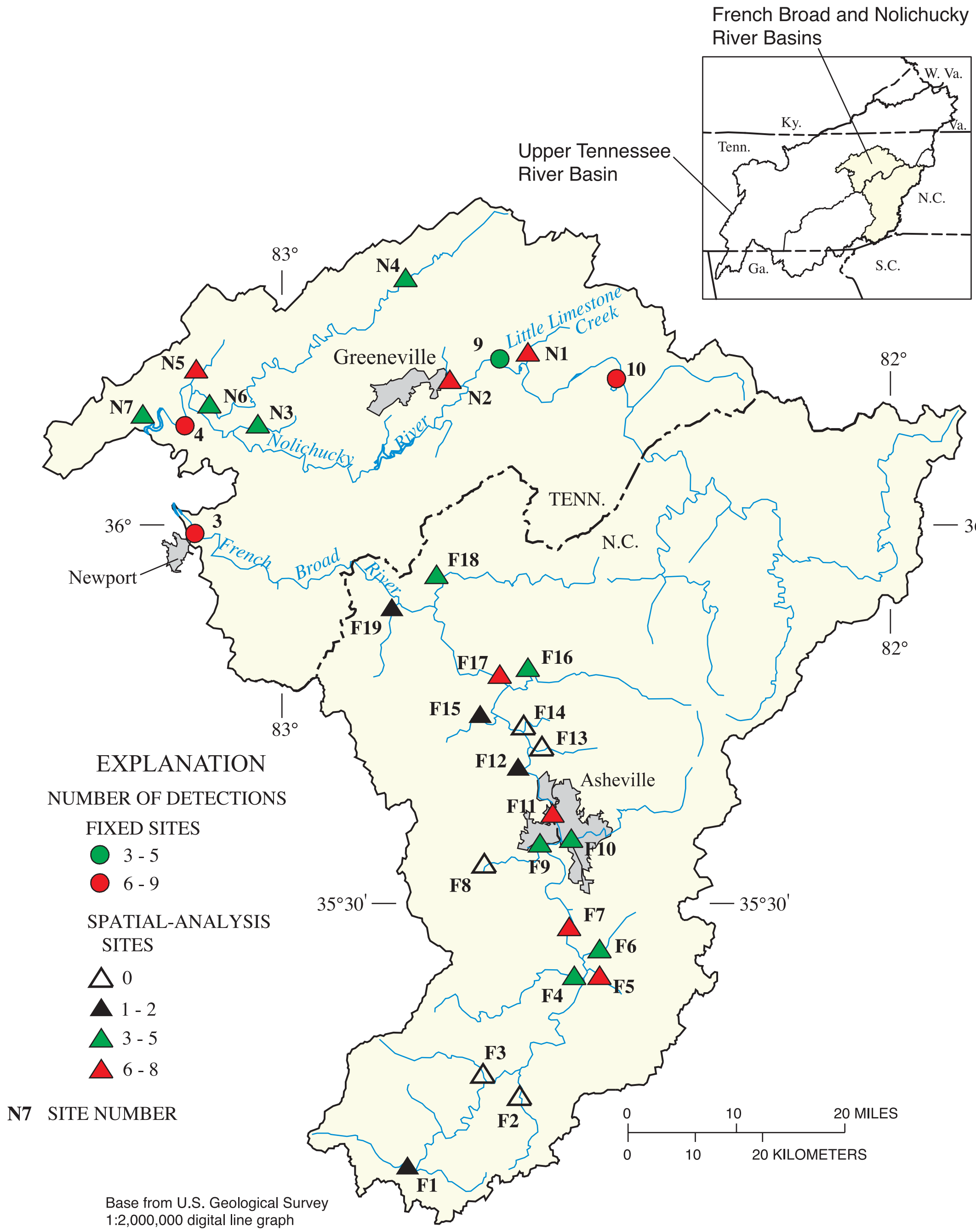

Figure 10. Pesticides detected in samples from 30 stream sites in the French Broad and Nolichucky River Basins, 1997.

Limestone Creek in samples from this period (fig. 10). Atrazine and deethylatrazine were detected in all samples, and tebuthiuron and metolachlor were detected in 8 of the 10 samples.

Eight detections occurred at the only site (Little Limestone Creek at Broylesville, Tenn.—site N1) that was not sampled during low-flow conditions in 1997. Little Limestone Creek was sampled several hours after a local thunderstorm during a declining stage with high turbidity conditions. Concentrations for several pesticides were elevated for this sample, including atrazine (0.999 µg/L), metolachlor (4.0 µg/L), acetochlor (0.393 µg/L), diuron (0.30 µg/L), and lindane (0.012 µg/L), which was the only exceedance of an aquatic-life criterion detected in stream samples from the spatial-analysis sites in the UTEN. The concentrations for metolachlor, diuron, and acetochlor in this sample were also the highest of all 423 samples (fixed and spatial-analysis sites) collected in the UTEN (1996-99); the atrazine concentration at Little Limestone Creek exceeded 99 percent of measured concentrations. The only detections of alachlor, acetochlor, and lindane at spatial-analysis sites in the French Broad and Nolichucky River Basins occurred at the Little Limestone Creek site. These data indicate that pesticide concentrations can vary significantly in streams during storm flows, particularly during the growing season.

In 1998, samples were collected at spatial-analysis sites and two fixed sites in the Holston River Basin. Seven different pesticides—five herbicides, one insecticide, and one metabolite—were detected in samples from the 12 sites. The number of pesticide detections per sample ranged from zero at Horse Creek near Kingsport, Tenn. (site H9, fig. 8), to four at the North Fork Holston River at Cloud Ford, Tenn. (site H7), and at two sites on Beaver Creek near Bristol, Tenn./Va. (sites H5 and H6) (fig. 8). Atrazine and metolachlor were the two most commonly detected pesticides. Atrazine was detected in 11 samples; metolachlor was detected in 7 samples. Pesticides were measured at relatively low concentrations (less than 0.05 μg/L) with no exceedances of human health or aquatic-life criteria.

At the 61 stream sites, 20 different pesticides were detected, and at least 1 pesticide was detected in 89 percent of the samples collected. Median concentrations of pesticides for all spatial-analysis samples equaled the MRL for all pesticides except atrazine and deethylatrazine. Pesticide concentrations most frequently exceeding the threshold concentration of 0.01 μg/L were atrazine (54 percent), tebuthiuron (41 percent), deethylatrazine (17 percent), metolachlor (16 percent), simazine (14 percent), and prometon (12 percent). Although the detection frequencies were lower for most pesticides at the spatial-analysis sample sites in comparison to the fixed sites, the same group of pesticides were most frequently detected at both sets of sites. Seven pesticides detected at the fixed sites were not detected at any of the spatial-analysis sites.

SUMMARY

The USGS conducted an assessment of pesticides in streams in the UTEN as part of the National Water-Quality Assessment Program. Thirteen stream sites were selected as fixed sampling sites to represent the diverse land uses, physiographic settings, and other drainage-basin characteristics in the UTEN, which includes parts of Tennessee, North Carolina, Virginia, and Georgia and drains about 21,400 mi^2. The fixed sites were sampled for pesticides at fixed intervals and supplemented with storm-flow samples. Samples also were collected at 61 additional sites in the major subbasins of the UTEN during the springs and summers of 1996, 1997, and 1998 to assess the spatial variation of pesticides during low flow in streams.

Pesticides that were detected frequently in streams in the UTEN were generally the pesticides having high estimated use in the basin. A total of 30 pesticides were detected in 362 samples collected at the 13 fixed sites. Herbicides were detected more frequently than insecticides, which is consistent with the greater use of herbicides in the UTEN. Of the 10 most frequently detected pesticides, 8 were herbicides and 1 was a metabolite of atrazine. Atrazine, metolachlor, and simazine, heavily used herbicides in the UTEN, were detected frequently in streams in the UTEN. The herbicides most frequently detected at concentrations at or greater than 0.01 μg/L were atrazine (in 59 percent of samples), tebuthiuron (41 percent), deethylatrazine (31 percent), metolachlor (24 percent), simazine (17 percent), and prometon (6.4 percent). The insecticides most frequently detected at concentrations at or greater than 0.01 μg/L were carbaryl (6.1 percent), diazinon (1.9 percent), carbofuran (1.7 percent), and chlorpyrifos (1.1 percent).

Pesticide detection frequencies also were associated with land use. Generally, the most frequently detected pesticides (atrazine, deethylatrazine, metolachlor, and simazine) were those applied to agricultural land. Detection frequencies of pesticides varied from site to site, reflecting differences in land use in the upstream drainages. Although Copper Creek near Gate City, Va., is an intensively agricultural site, metolachlor was detected in only 18 percent of the samples from the Copper Creek site. Tebuthiuron and prometon, which are most commonly used in noncropland areas and on pastureland, also were among the most frequently detected herbicides in the UTEN study.

Pesticide detection frequencies for the UTEN were compared with the national summary compiled by the USGS from NAWQA studies (1992-98); atrazine, deethylatrazine, tebuthiuron, and napropamide were more frequently detected in the UTEN study than in the national summary of pesticide detections for streams with agricultural drainages and for streams draining areas of mixed land use. Atrazine and deethylatrazine were detected in about 99 and

98 percent of samples, respectively, in the UTEN compared to the national average of about 85 and 69 percent, respectively, for agricultural sites. Tebuthiuron was detected in 62 percent of water samples from agricultural sites in the UTEN as compared to about 22 percent of samples from agricultural sites nationwide. Pesticides that were detected considerably less frequently in the UTEN streams than at the nationwide agricultural sites included alachlor, acetochlor, carbofuran, diazinon, metolachlor, metribuzin, prometon, and simazine. Comparison of detection frequencies at sites with mixed land-use drainages in the UTEN with the national averages reveal results similar to the agricultural sites with the exception of metolachlor, which was detected more frequently in the UTEN.

Low concentrations (generally less than 0.10 μg/L) of pesticides were detected at all 13 fixed sites in the UTEN. Concentrations of individual pesticides ranged from 0.001 to 2.0 μg/L. Atrazine, bromacil, dichlorprop, 2,6-diethylaniline, metolachlor, metribuzin, simazine, carbaryl, carbofuran, and diazinon were detected in samples at concentrations greater than 0.10 μg/L. In 47 of the 362 samples collected, one or more pesticides were detected in samples at concentrations greater than 0.10 μg/L. Concentrations of atrazine exceeded 0.10 μg/L in 37 samples, and concentrations of metolachlor exceeded 0.10 μg/L in 11 samples. Seven samples had concentrations of one or more pesticides exceeding 0.50 μg/L, and only four samples had concentrations of one or more pesticides exceeding 1.0 μg/L.

Peak pesticide concentrations were detected at the agricultural sites in late spring and early summer, generally coinciding with pesticide applications and the first substantial runoff event following pesticide applications. Concentrations of atrazine and metolachlor were elevated more frequently than concentrations of other pesticides, and most of the elevated concentrations were detected at the agricultural sites. The maximum pesticide concentration of 2 μg/L was detected for atrazine at the Nolichucky River near Lowland, Tenn. Agricultural land accounts for only about 39 percent (650 mi^2) of the drainage upstream of this site; however, most of the area adjacent to or directly upstream from the sampling site is predominantly agricultural. The maximum concentration detected for metolachlor was 1.3 μg/L in a sample collected at Big Limestone Creek near Limestone, Tenn., which has a watershed that consists of about 83 percent agricultural land. Elevated concentrations of several pesticides including atrazine, deethylatrazine, metolachlor, tebuthiuron, simazine, prometon, and chlorpyrifos were detected during the growing season at most fixed sites.

Concentrations of pesticides and metabolites in streams in the UTEN generally were well below established water-quality criteria. Although most of the water samples collected in the UTEN study area contained detectable concentrations of one or more pesticides, none of the concentrations exceeded human health standards. Only 21 of the 31 pesticides detected, however, have established MCL or HAL criteria. Of the 14 pesticides detected that have established criteria for the protection of aquatic life, only carbaryl, lindane, diazinon, and atrazine were detected at concentrations exceeding the criteria in 7 of the 362 samples collected at fixed sites.

Spatial analysis of pesticide detections and concentrations in several of the subbasins of the UTEN indicated that the network of fixed sites in the UTEN were generally representative of conditions throughout the basin. The most frequently detected pesticides in water samples from the spatial-analysis sites were atrazine, deethylatrazine, metolachlor, tebuthiuron, simazine, and prometon. Only 1 of the 61 stream samples was collected under hydrologic conditions that did not represent low flow. This site, Little Limestone Creek at Broylesville, Tenn., was sampled several hours after a major storm. High concentrations of several pesticides were measured at this site, including one exceedance of the aquatic-life criterion for lindane. Overall, concentrations of pesticides at spatial-analysis sites were lower than at fixed sites in every subbasin; however, a greater number of detections usually occurred at sites that were influenced by urban or industrial land use. Of the 47 pesticides that were analyzed in all samples, 7 pesticides detected at the fixed sites were not detected at any of the spatial-analysis sites. Conversely, only one of the pesticides (terbacil) detected at a spatial-analysis site was not detected in samples collected at the fixed sites.

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APPENDIX

Appendix A. Sites sampled for spatial analysis of pesticides in the upper Tennessee River Basin, 1996-98

[USGS, U.S. Geological Survey; dates given as month-day-year]

Site number	USGS station name	USGS station number	Sample date	Drainage area (square miles)	Land use (percent)				
					Forest	Pasture	Cropland	Urban	Other
	Clinch River Basin (fig. 8)								
C1	Little River at U.S. Highway 19 near Wardell, Va.	03522000	6-11-96	105	49.8	46.4	0.7	1.1	0.2
C2	Big Cedar Creek below Daugherty’s Cave near Lebanon, Va.	03523080	6-10-96	86	50.6	44.6	1.2	2.8	0.0
C3	Guest River at Esserville, Va.	03524330	5-14-96	23	78.5	13.0	0.2	7.3	0.9
C4	Guest River at Coeburn, Va.	03524500	5-14-96	87	78.0	13.7	0.2	7.6	0.4
C5	Blackwater Creek at Newman Ridge near Kyles Ford, Tenn.	0352763950	5-20-98	32	76.9	20.4	2.0	0.6	0.1
	Powell River Basin (fig. 8)								
P1	Powell River near Esserville, Va,	03529050	6-3-96	7	84.3	10.9	0.1	4.6	0.1
P2	Powell River at Norton, Va.	03529075	6-4-96	11	86.1	10.4	0.0	3.4	0.1
P3	Powell River at Blackwood, Va.	03529295	6-4-96	25	87.0	9.0	0.0	3.6	0.2
P4	North Fork Powell River at Keokee, Va.	03530150	5-15-96	9	85.1	9.9	0.2	2.2	2.6
P5	North Fork Powell River near Dryden, Va.	03530225	6-6-96	23	82.6	11.3	0.4	4.1	1.6
P6	North Fork Powell River at Penningham Gap, Va.	03530550	6-12-96	89	81.7	14.0	0.6	3.2	0.5
P7	Wallen Creek below Lone Branch near Jonesville, Va.	03531518	5-20-98	44	63.3	33.1	2.6	0.5	0.0
P8	Indian Creek at Greers Chapel, Tenn.	03531900	5-21-98	52	57.2	39.9	2.0	0.8	0.1
	Holston River Basin (fig. 8)								
H1	North Fork Holston River near Saltville, Va.	03488000	6-13-96	223	72.9	24.7	1.0	0.6	0.1
H2	South Fork Holston River above Damascus, Va.	03472150	7-15-98	136	66.1	30.4	2.1	1.3	0.1
H3	Laurel Creek at Vails Mill at Damascus, Va.	03472700	7-15-98	158	86.7	11.0	1.1	1.2	0.0
H4	Big Moccasin Creek at Collinwood near Hansonville, Va.	03489870	7-14-98	329	74.9	22.4	0.8	0.9	0.2
H5	Beaver Creek at Bristol, Va.	03478400	7-15-98	26	31.5	48.7	8.8	10.6	0.4
H6	Beaver Creek near Avoca below Bristol, Tenn.	03478592	7-16-98	62	35.2	36.9	5.8	21.8	0.3
H7	North Fork Holston River near Cloud Ford, Tenn.	03490090	7-14-98	717	70.8	25.4	1.6	1.6	0.2
H8	Reedy Creek at Gibsontown near Kingsport, Tenn.	03487595	7-13-98	53	49.9	33.0	3.3	13.6	0.1

Appendix A. Sites sampled for spatial analysis of pesticides in the upper Tennessee River Basin, 1996-98—Continued

Site number	USGS station name	USGS station number	Sample date	Drainage area (square miles)	Land use (percent)				
					Forest	Pasture	Cropland	Urban	Other
	Holston River Basin (fig. 8)—Continued								
H9	Horse Creek at Smoky Valley near Kingsport, Tenn.	03487521	7-13-98	44	52.0	36.4	3.6	7.8	0.2
H10	Big Creek near Rogersville, Tenn.	03491000	7-17-98	48	61.4	33.2	4.3	1.0	0.1
--	Watauga River near Watauga Point, Tenn. (not shown on fig. 8)	03483960	7-16-98	750	78.2	16.0	1.4	2.9	1.5
	Emory River Basin and other tributaries to the Tennessee River (fig. 9)								
L1	Little River at Coulter Bridge near Maryville, Tenn.	03497450	7-9-96	192	94.3	4.6	0.2	0.7	0.2
L2	Little River at Rockford, Tenn.	03498863	6-24-96	300	76.7	18.5	1.9	2.7	0.2
W1	Whites Creek near Roddy, Tenn.	03541498	6-25-96	118	80.5	15.9	2.9	0.4	0.3
W2	Piney River above mouth of Sock Creek near Spring City, Tenn.	03542495	6-27-96	61	71.0	21.5	3.1	4.1	0.3
E1	Obed River at Potters Ford near Crossville, Tenn.	03538860	7-25-96	107	49.0	39.5	7.0	2.7	1.8
E2	Clear Creek at Norris Ford near Jones Knob, Tenn.	03539717	7-23-96	81	60.3	29.4	5.4	0.4	0.2
E3	Clear Creek at Waltham Ford Bridge near Frankfort, Tenn.	03539735	7-22-96	146	68.2	24.9	3.9	0.3	0.2
E4	Daddys Creek at Devil’s Breakfast Table, Tenn.	03539690	7-24-96	174	60.5	29.8	4.4	4.2	1.1
E5	Obed River near Lancing, Tenn.	03539800	6-30-98	518	64.2	27.6	4.3	2.4	0.9
E6	Emory River near Lancing, Tenn.	03538580	6-26-96	92	89.3	9.8	0.7	0.2	0.0
	French Broad River Basin (fig. 10)								
F1	French Broad River at Rosman, N.C.	03439000	7-9-97	69	92.8	4.9	1.4	0.8	0.1
F2	Little River at Cascade Lake Road near Little River, N.C.	0344150700	7-9-97	43	91.7	4.9	1.0	1.2	1.2
F3	Davidson River at Old Henderson Highway at Brevard, N.C.	0344114090	7-8-97 7-30-97	47	95.4	2.0	0.8	1.5	0.3
F4	Mills River at Hopper Lane near Mills River, N.C.	0344602100	4-17-97	73	90.3	7.7	1.2	0.4	0.4
F5	Mud Creek at Naples, N.C.	0344700000	4-16-97	110	48.0	32.4	6.3	13.0	0.3
F6	Cane Creek at U.S. 25 at Fletcher, N.C.	0344766600	4-17-97	82	68.0	28.0	1.9	1.9	0.2
F7	French Broad River at Glenn Bridge Road near Arden, N.C.	0344776625	7-29-97	651	73.9	17.9	3.4	4.4	0.4
F8	South Hominy Creek at Candler, N.C.	0344834200	4-9-97	38	80.1	15.3	0.3	4.1	0.2

Appendix A. Sites sampled for spatial analysis of pesticides in the upper Tennessee River Basin, 1996-98—Continued

Site number	USGS station name	USGS station number	Sample date	Drainage area (square miles)	Land use (percent)				
					Forest	Pasture	Cropland	Urban	Other
	French Broad River Basin (fig. 10)—Continued								
F9	Hominy Creek near West Asheville, N.C.	0344878100	4-16-97	103	67.8	18.6	1.1	12.3	0.2
F10	Swannanoa River at Biltmore, N.C.	03451000	4-15-97	130	79.3	8.5	0.6	10.9	0.7
F11	French Broad River at Asheville, N.C.	03451500	7-30-97	944	73.2	16.6	2.6	7.0	0.6
F12	Newfound Creek near Alexander, N.C.	0345169000	4-8-97	33	48.0	37.6	6.6	7.7	0.0
F13	Reems Creek at New Stock Road near Weaverville, N.C.	0345182580	4-9-97	34	77.9	14.9	1.1	6.0	0.1
F14	Flat Creek near Weaverville, N.C.	0345195390	4-10-97	25	57.4	32.2	3.7	6.7	0.1
F15	Sandymush Creek near Volga, N.C.	0345199400	4-8-97	45	72.1	23.5	3.5	0.9	0.0
F16	Ivy River at Marshall, N.C.	0345292005	7-8-97	154	75.1	20.1	2.2	2.6	0.0
F17	French Broad River at Marshall, N.C.	03453500	7-31-97	1331	71.3	18.8	2.8	6.6	0.5
F18	Big Laurel Creek near Stackhouse, N.C.	03454000	4-22-97	58	91.6	6.8	0.9	0.7	0.0
F19	Spring Creek at NC 209 near Hot Springs, N.C.	0345458780	4-21-97	70	91.4	7.8	0.5	0.3	0.0
	Nolichucky River Basin (fig. 10)								
N1	Little Limestone Creek at Broylesville, Tenn.	03465650	7-1-97	27	15.1	64.8	10.9	9.1	0.1
N2	Sinking Creek at WWTP near Afton, Tenn.	03466233	7-16-97	14	11.9	68.7	16.7	2.5	0.2
N3	Little Chucky Creek near Warrensburg, Tenn.	03466698	6-25-97	39	28.3	55.7	9.4	6.5	0.1
N4	Lick Creek near Lick Creek Mill near Baileyton, Tenn.	03466835	7-17-97	78	38.5	51.4	7.9	2.1	0.1
N5	Bent Creek near Silver City, Tenn.	03467485	6-24-97	39	21.8	63.4	9.7	4.9	0.1
N6	Lick Creek at Scoot Mill, Tenn.	03467300	6-25-97	262	31.1	55.6	9.7	3.6	0.1
N7	Long Creek near Lowland, Tenn.	03468065	6-24-97	39	23.0	58.7	11.5	6.7	0.2
	Pigeon River Basin								
PI1	Pigeon River near Denton, Tenn.	03461080	7-10-96	568	82.1	11.2	1.2	5.2	0.3