THE SPATIAL DISTRIBUTION OF DISSOLVED PESTICIDES IN SURFACE WATER OF THE APALACHICOLA-CHATTAHOOCHEE-FLINT RIVER BASIN IN RELATION TO LAND USE AND PESTICIDE RUNOFF-POTENTIAL RATINGS, MAY 1994

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Abstract. During baseflow conditions in May 1994, streamwater samples were collected and analyzed from 67 locations in the Apalachicola-Chattahoochee-Flint (ACF) River basin. These data were used to evaluate the number and concentrations of dissolved pesticides present in streams in relation to (1) predominant land uses in the ACF River basin; (2) location along the mainstem of the Chattahoochee, Flint, and Apalachicola Rivers and selected large tributaries; and (3) pesticide runoff characteristics.

In comparisons of streamwater samples from groups of small watersheds representing the predominant land uses in the ACF River basin (referred to as indicator sites), pesticides were detected most frequently and at highest concentrations in urban watersheds; followed by suburban, rowcrop agriculture, poultry and livestock production, and forested watersheds. Herbicides used for selective preemergent weed control had the widest distribution among indicator sites; however, herbicides used for nonselective weed control were present at highest concentrations. Herbicides used for postemergent weed control were rarely detected in streamwater samples from indicator sites, or mainstem and large tribuatary sites that possess mixed land uses (referred to as integrator sites).

The insecticides carbaryl, chlorpyrifos, and diazinon were detected with greatest frequency in streamwater samples from (1) indicator sites in areas of urban and suburban land use, and (2) integrator sites located near the Atlanta Metropolitan area. These sites comprised 18 of 22 sites where insecticide concentrations exceeded existing standards or guidelines for protection of aquatic life.

Pesticides with long soil half-lifes, high water solubilities, and low organic carbon partitioning coefficients were detected with greatest frequency and highest concentrations in streamwater samples. These compounds have large runoff-potential ratings, and include several of the herbicides used for selective preemergent weed control, all the herbicides used for nonselective weed control, and the insecticide diazinon. Pesticides having medium runoff-potential ratings were detected primarily in streamwater samples from sites in areas of suburban and urban land use and from integrator sites located near the Atlanta Metropolitan area.

INTRODUCTION

The Apalachicola-Chattahoochee-Flint (ACF) River basin encompasses extensive areas of forested land (58 percent) and agricultural land (30 percent), and a smaller percentage of urban land (6.0 percent), wetlands (4.3 percent), and open water (1.7 percent). Pesticides are used extensively on agricultural and urban lands in the ACF River basin, with some additional use on forested land (related to reforestation following clearcutting), and on open water (to control aquatic weeds and mosquitoes) (Stell *et al.*, 1995).

For the period 1990-93, Anderson and Gianessi (1995) estimated an annual average of 17 million pounds of pesticide active ingredients were applied to agricultural land in the ACF River basin. These estimates included 147 of the 210 most-used compounds in the United States and summarized pesticide use on rowcrops, small-grain crops, seed crops, forage crops, fruits, nuts, vegetables, tobacco, and pasture land. However, the types and amount of pesticides applied on silviculture, horticulture, residential, industrial-commercial, and institutional land in the ACF is unknown. Many of the pesticides used have been rated at moderate or high potential to runoff into streams (Goss and Wauchope, 1990).

In other parts of the United States, some of these pesticides have exceeded drinking-water standards or aquatic health criteria (Wauchope *et al.*, 1994; Larson and others, *in press*). Although state environmental protection agencies indicate that pesticides are a priority issue, most current assessment programs within the ACF River basin do not (1) collect water-column data for most current-use pesticides; or (2) assess inputs of pesticides from nonpoint sources when evaluating impairments to streams (Alabama Department of Environmental Management, 1992; Georgia Department of Natural Resources, 1994; Hand and Paulic, 1992).

A retrospective analysis of available pesticide data for the ACF River basin collected from 1960-91, indicated that existing data collected by Federal agencies also are inadequate for assessing the distribution of current-use pesticides in the watershed (Stell *et al.*, 1995).

In 1991, the U.S. Geological Survey (USGS) implemented a National Water-Quality Assessment Program (NAWQA) study of the ACF River basin and 59 other hydrologic systems in the United States, in order to assess the status of and trends in the quality of the Nation's water resources (Leahy *et al.*, 1990). The NAWQA program is using a multiscale, interdisciplinary approach to assess water-quality conditions in the United States and has targeted pesticides as a water-quality concern (Gilliom *et al.*, 1995). A total of eight synoptic studies of varying scope were conducted from 1993 through 1995 by the ACF NAWQA, in order to understand the spatial distribution of water-quality conditions in the watershed.

Purpose and scope

This paper describes the number and concentrations of dissolved pesticides present in streams in relation to (1) predominant land uses in the ACF River basin; (2) location along the mainstem of the Chattahoochee, Flint, and Apalachicola Rivers and large tributaries; and (3) pesticide runoff characteristics. Results are based on dissolved pesticide-concentration data for streamwater samples from 37 indicator sites and 30 integrator sites that were collected during baseflow conditions in May 1994.

Indicator sites were located in small watersheds (average drainage area of about 33 square miles) that were classified according to hydrogeologic setting and a predominant land use (Figure 1). Integrator sites included 18 large tributaries (average drainage area of about 320 square miles) and 12 sites located on the mainstems of the Apalachicola, Chattahoochee, and Flint Rivers. Integrator sites have mixed land uses and were classified according to hydrogeologic setting and location relative to the Atlanta Metropolitan area (Figure 1). Data from indicator sites are the basis for comparison of pesticide loadings to streams related to predominant land uses (and associated pesticide-use practices) in the ACF River basin. Data from integrator sites are the basis for evaluation of the spatial distribution of pesticides in the basin. The locations and descriptions of streamwater sampling sites and tabulations of water-quality data are available on the World Wide Web (at **http://wwwga.usgs.gov/nawqa/**).

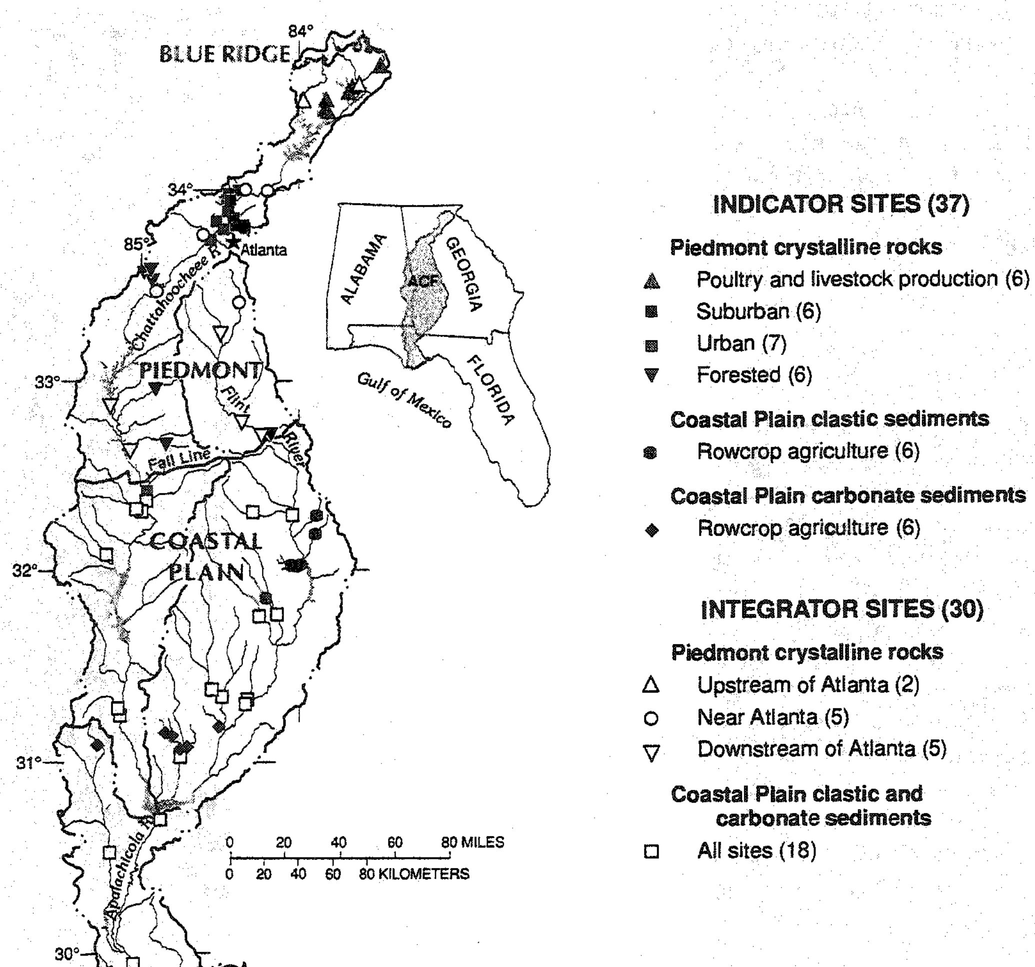

Figure 1. Location of Apalachicola–Chattahoochee–Flint River basin in parts of Georgia, Alabama, and Florida and sampling sites.

Comparisons to pesticide-use patterns in the ACF River basin are based on reports by Stell *et al.*, (1995), Anderson and Gianessi (1995), and Landry (1996). Comparisons to pesticide runoff characteristics are based on ratings developed by Goss and Wauchope (1990).

Methods

Streamwater samples were collected according to Shelton (1994) using depth-integrating Teflon[1/] samplers. Streams were sampled at five to eight equal-width increments. Samples were filtered on site and extracted using solid-phase cartridges prior to shipping and analysis at the USGS National Water-Quality Laboratory, Arvada, Colo. Samples were analyzed for 84 pesticide residues using a Gas Chromatography/Mass Spectrometry method (Zaugg *et al.*, 1995) and a High Performance Liquid Chromatography method (Werner *et al.*, 1996). Detection limits (of from 0.001 to 0.050 micrograms per liter) generally are several orders of magnitude lower than existing standards and guidelines for finished drinking-water supplies. Samples were analyzed for 49 of 147 pesticides used on agricultural land in the ACF River basin, 23 registered pesticides with no known use on agricultural land, 7 pesticide soil metabolites, and 5 pesticides that are banned from use.

Pesticide use relative to the compounds analyzed and their runoff-potential ratings are summarized in Table 1. Included are compounds with use greater than or equal to 0.1 percent of the total agricultural use of herbicides, insecticides, or fungicides in the ACF River basin; other detected compounds with no known agricultural use also are included in Table 1. The pesticides analyzed in streamwater samples include the herbicides, insecticides and nematicides, and fungicides by weight of about 77, 81, and 53 percent, respectively, used on agricultural land in the ACF River basin, and an unknown amount of additional use on other land.

Antecedent conditions

The sampling period in May 1994, closely followed the period of greatest planting activity in agricultural areas and an active period of turf management in most other areas in the ACF River basin (Table 2). The sampling period was preceded by most applications of preplant and preemergent herbicides, soil fumigants, and nematicides; and was prior to many applications of postemergent herbicides, fungicides, foliar insecticides, and harvest aids (Stell *et al.*, 1995; Anderson and Gianessi, 1995; Landry, 1996). All sites were sampled during stable or falling streamflows, often referred to as a baseflow condition, with little or no rainfall in the days prior to the sampling period (Figure 2). Generally, pesticide concentrations are lower and exhibit less temporal variability during baseflow conditions. Samples were collected during baseflow condition so that differences in pesticide occurrence could be associated more closely to hydrogeologic setting and land use. Streamflow conditions were at or below normal during the sampling period.

In the Piedmont hydrogeologic setting, streamflow yield was below the median streamflow yield for the period of record, indicating dry antecedent conditions (Figure 2). Streamflow yields during the sampling period were near normal in parts of the Coastal Plain underlain by carbonate sediments and below normal in parts of the Coastal Plain underlain by siliciclastic sediments.

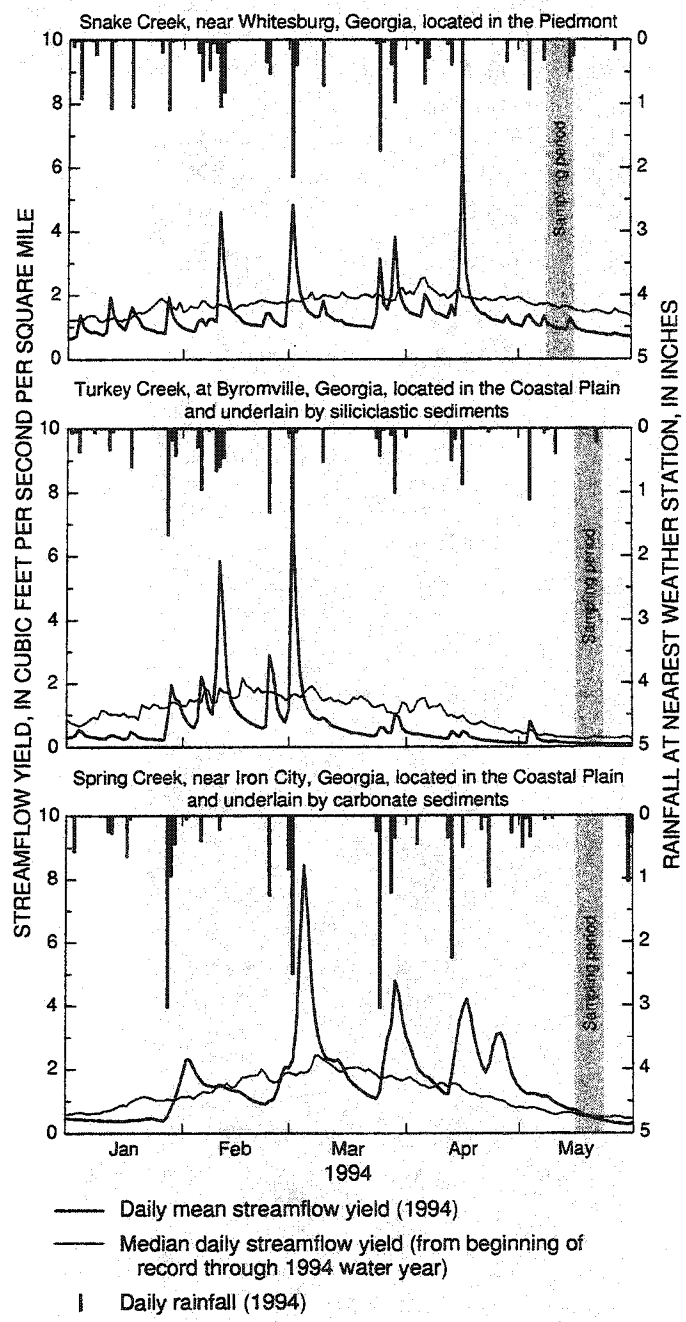

Figure 2. Streamflow and rainfall prior to and during May 1994 sampling period.

[1/]Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Table 1. Pesticide use in the Apalachicola-Chattahoochee-Flint River basin relative to surface runoff-potential ratings and analysis in streamwater samples

[pesticides shown in bold were detected in May, 1994; lbai/yr, pounds of active ingredient per year; na, not applicable]

Pesticide type and total use		Surface runoff-potential ratings (from Goss and Wauchope, 1990) Pesticide name and agricultural use as a percentage of use of pesticides of that type (from Anderson and Gianessi, 1995)			
		Small	Medium	Large	Not rated
Herbicides 3,800,000 lbai/yr	analyzed		**Pendimethalin (9.4)** Ethalfluralin (5.1) **Cyanazine (4.0)** Benefin (3.0) **Alachlor (2.2)** Acifluorfen (0.8) Oryzalin (0.3) Chloramben (0.1) **Propanil (na)** Bentazon (9.0) **2,4-D (5.0)** **Trifluralin (3.3)** 2,4-DB (2.7) Dicamba (1.2) **Metribuzin (0.3)** **DCPA (0.1)** EPTC (0.1)	**Metolachlor (10.9)** **Fluometuron (3.4)** **Butylate (2.2)** **Simazine (0.7)** **Terbacil (0.1)** Napropamide (0.1) **Bromacil (na)** **Pronamide (na)** **Atrazine (8.1)** Norflurazon (2.5) **Diuron (1.5)** Picloram (0.5) **Linuron (0.1)** **Tebuthiuron (na)** **Prometon (na)**	**Deethylatrazine (na)**
	not analyzed	Paraquat (2.4)	Chlomazone (1.9) Methazole (0.3) Fluazifop (0.1) Vernolate (1.3) Diclofop (0.1)	Glyphosate (2.6) Ametryn (0.1) Prometryn (0.2) Bensulide (0.1)	MSMA (10.6) Sethoxydim (1.0) Imazethapyr (0.1) Endothall (0.1) DSMA (1.1) Pyridate (1.0) Fenoxaprop (0.1) Chlorimuron (0.1)
Insecticides 4,000,000 lbai/yr	analyzed	**Malathion (9.0)** Permethrin (0.3)	**Chlorpyrifos (17.9)** Methomyl (8.6) Methyl parathion (5.6) Propargite (2.1) Ethyl parathion (0.7) Oxamyl (0.1) Aldicarb (15.4) **Carbaryl (7.3)** Disulfoton (3.0) Terbufos (1.8) Esfenvalerate (0.2)	Fonofos (3.6) Carbofuran (1.4) **Diazinon (0.6)** Phorate (2.6) Azinphos-methyl (0.6) Lindane (0.2)	**Dieldrin (na)**
	not analyzed	Dicofol (1.2) Dicrotophos (0.5) Cypermethrin (0.3)	Acephate (4.0) Profenofos (1.6) Fenbutatin-oxide (1.0) Sulprofos (0.3) Methidathion (0.2) Trichlorfon (0.1) Endosulfan (2.1) Dimethoate (1.6) Methamidophos (0.5) Ethoprop (0.3) Phosmet (0.2)	Thiodicarb (3.9) Cyfluthrin (0.3) Fenamiphos (0.7) Ethion (0.1)	Lambdacyhalothrin (0.2)
Fungicides 5,300,000 lbai/yr	analyzed		Chlorothalonil (53.1)		
	not analyzed	PCNB (3.2) Dodine (0.3)	Mancozeb (3.3) Ferbam (0.4) Captan (0.3) Etridiazole (0.1) Maneb (0.6) Thiophanate-methyl (0.4) Carboxin (0.2)	Benomyl (0.4) Propiconazole (0.3)	Sulfur (34.6) Copper (0.6) Triphenyltin-0H (1.6) Ziram (0.4)

Table 2. Crop acreage, and crop and turf management calender for the Apalachicola-Chattahoochee-Flint River basin
[na, not applicable]

Crop or turf	Acreage planted[1/]	Month of Year											
		J	F	M	A	M	J	J	A	S	O	N	D
Small grains	173,000	Growth	Growth	Growth	Growth	Growth/Harvest	Harvest				Planting	Planting	Planting
Vegetables-summer	27,600			Planting	Planting	Planting	Harvest	Harvest	Harvest				
Corn	286,000			Planting	Planting	Planting	Growth	Growth	Harvest	Harvest	Harvest		
Tobacco	3,140			Planting	Planting	Growth	Growth/Harvest	Harvest	Harvest				
Fruits	14,100			Bloom	Bloom	Growth	Growth	Harvest	Harvest	Harvest			
Pecans	84,000	Harvest			Bloom	Growth	Growth	Growth	Growth	Growth	Growth/Harvest	Harvest	Harvest
Peanuts	512,000				Planting	Planting	Growth	Growth	Growth	Harvest	Harvest		
Cotton	215,000				Planting	Planting	Planting/Growth	Growth	Growth	Growth/Harvest	Harvest	Harvest	Harvest
Sorghum	25,700				Planting	Planting	Planting	Growth	Growth	Growth	Harvest	Harvest	
Soybeans	137,000					Planting	Planting	Growth	Growth	Growth	Growth/Harvest	Harvest	
Cool season turf	na	Growth	Growth	Growth	Growth	Growth				Growth/establishment	Growth/establishment	Growth/establishment	Growth/establishment
Warm season turf	na				Growth	Growth	Growth	Growth	Growth	Growth	Growth		

[1/]Average planted acreage for 1990-93 from Anderson and Gianessi (1995)

PESTICIDE OCCURRENCE AT INDICATOR SITES

Pesticides were detected with greatest frequency and largest summed concentration in streamwater samples that were collected from indicator sites in areas of urban land use (Table 3). A pattern of decreasing average detection frequency and summed concentrations was observed in streamwater samples from indicator sites with urban, suburban, rowcrop agriculture (in areas underlain by either siliciclastic or carbonate sediments), poultry and livestock production, and forested land use (Figure 3). Pesticide concentrations in streamwater samples from each indicator site were well below existing standards and guidelines for lifetime exposure in drinking water (Nowell and Resek, 1994). However, concentrations of the insecticide diazinon, carbaryl, or chlorpyrifos exceeded existing standards or guidelines for protection of freshwater aquatic life in streamwater samples from each site in suburban and urban areas and from one site in rowcrop agricultural areas.

Herbicides were the most frequently detected type of pesticide present in streamwater samples from indicator sites in the ACF River basin. Herbicides used for selective preemergent weed control were detected at indicator sites in each of the targeted land uses; atrazine was the most commonly detected compound of this type. Streamwater samples from indicator sites in areas of forest land and livestock and poultry production had fewer detections and lower concentrations of preemergent herbicides than indicator sites in other land uses. Streamwater samples from the remaining indicator sites in urban, suburban, and rowcrop agricultural areas had only minor differences in the average number of detections and summed concentrations of selective preemergent herbicides.

Several herbicides used for selective preemergent weed control were detected primarily in indicator sites in either rowcrop agricultural or suburban and urban land use; which may be a result of the legally restricted use of several of these compounds. For example, the restricted-use compounds alachlor, cyanazine, and fluometuron, were detected only in streamwater samples from indicator sites that drain areas having crops for which these compounds are registered. The general-use compounds simazine, pendimethalin, and metribuzin primarily were detected in urban and suburban areas.

Detections of herbicides primarily used for nonselective weed control also were distributed among the various types of indicator sites, with detections in streams in suburban, urban and row crop agricultural land uses (Table 3). However, the average summed concentration of these nonselective herbicides in streamwater samples from indicator sites in urban areas far exceeds that of all pesticides in all other indicator sites (Figure 3). Streamwater samples from indicator sites in areas of urban land use contained an average of about 1.5 micrograms per liter of compounds primarily used for nonselective weed control; including diuron, linuron, prometon, and tebuthiuron.

Table 3. Dissolved pesticides present in streamwater samples from indicator sites in the Apalachicola-Chattahoochee-Flint River basin, May 1994
[concentrations are in micrograms per liter; det., number of detections, in percent; max. conc., maximum concentration; <, less than]

Pesticide detected	Piedmont crystalline rocks								Coastal Plain siliciclastic sediments		Coastal Plain carbonate sediments	
	Forested sites		Poultry and livestock production sites		Suburban sites		Urban sites		Rowcrop agriculture sites		Rowcrop agriculture sites	
	det. (%)	max. conc.	det. (%)	max. conc.	det. (%)	max. conc	det. (%)	max. conc	det. (%)	max. conc	det. (%)	max. conc
Compounds used primarily as selective preemergent herbicides												
Alachlor	0	<.002	0	<.002	0	<.002	0	<.002	17	.018	17	.003
Atrazine	0	<.001	50	.009	100	.040	100	.11	100	.050	83	.18
Butylate	17	.004	0	<.002	0	<.002	0	<.002	0	<.002	0	<.002
Cyanazine	0	<.004	0	<.004	0	<.004	0	<.004	33	.041	0	<.004
DCPA	0	<.002	0	<.002	0	<.002	14	.005	0	<.002	0	<.002
Deethylatrazine	0	<.002	0	<.002	33	.004	14	.011	17	.003	33	.010
Fluometuron	0	<.010	0	<.010	0	<.010	0	<.010	0	<.010	17	.020
Metolachlor	0	<.002	67	.006	17	.003	43	.008	67	.10	67	.043
Metribuzin	0	<.004	0	<.004	0	<.004	57	.021	17	.015	0	<.004
Pendimethalin	0	<.004	0	<.004	83	.017	0	<.004	0	<.004	0	<.004
Pronamide	0	<.003	0	<.003	17	.007	0	<.003	0	<.003	0	<.003
Simazine	0	<.005	0	<.005	83	.068	100	.31	0	<.005	0	<.005
Terbacil	0	<.007	0	<.007	0	<.007	0	<.007	0	<.007	17	.007
Trifluralin	0	<.002	0	<.002	0	<.002	0	<.002	17	.014	0	<.002
Compounds used primarily as selective postemergent herbicides												
2,4-D	0	<.023	0	<.023	17	.48	43	.030	0	<.023	0	<.023
Compounds used primarily as nonselective vegetation control herbicides												
Bromacil	0	<.040	0	<.040	0	<.040	14	1.4	0	<.040	0	<.040
Diuron	0	<.012	0	<.012	17	.58	86	.98	0	<.012	0	<.012
Linuron	0	<.002	0	<.002	0	<.002	14	.058	0	<.002	0	<.002
Prometon	0	<.018	0	<.018	50	.010	100	.046	0	<.018	0	<.018
Tebuthiuron	0	<.010	0	<.010	50	.15	100	6.4	17	.018	0	<.010
Compounds used primarily as insecticides												
Carbaryl	0	<.003	0	<.003	50	.046	86	.14	17	.012	0	<.003
Chlorpyrifos	0	<.004	0	<.004	17	.010	86	.015	0	<.004	0	<.004
Diazinon	0	<.002	0	<.002	100	.065	100	.079	17	.012	0	<.002
Dieldrin	0	<.001	0	<.001	17	.009	0	<.001	0	<.001	0	<.001

Herbicides primarily used for selective postemergent weed control were only rarely detected and only in streamwater samples from indicator sites in urban and suburban areas. The postemergent herbicide 2,4-D was the only compound of this type detected at indicator sites—it was present in streamwater samples from one suburban and three urban indicator sites. However, the sampling period may have preceded the principal application period of postemergent herbicides on some major crops, precluding their detection in areas of rowcrop agriculture.

Insecticides were detected almost exclusively (30 of 32 detections) in streamwater samples from indicator sites in areas of urban and suburban land use. Diazinon was the most frequently detected insecticide, followed by carbaryl and chlorpyrifos. With the exception of dieldrin, the insecticides detected in urban and suburban areas are packaged for numerous general uses for management of turf, ornamental, and garden pests. Prior to a U.S. Environmental Protection Agency ban in 1987, dieldrin was applied as a foundation treatment to control termites; chlorpyrifos currently is used for this purpose.

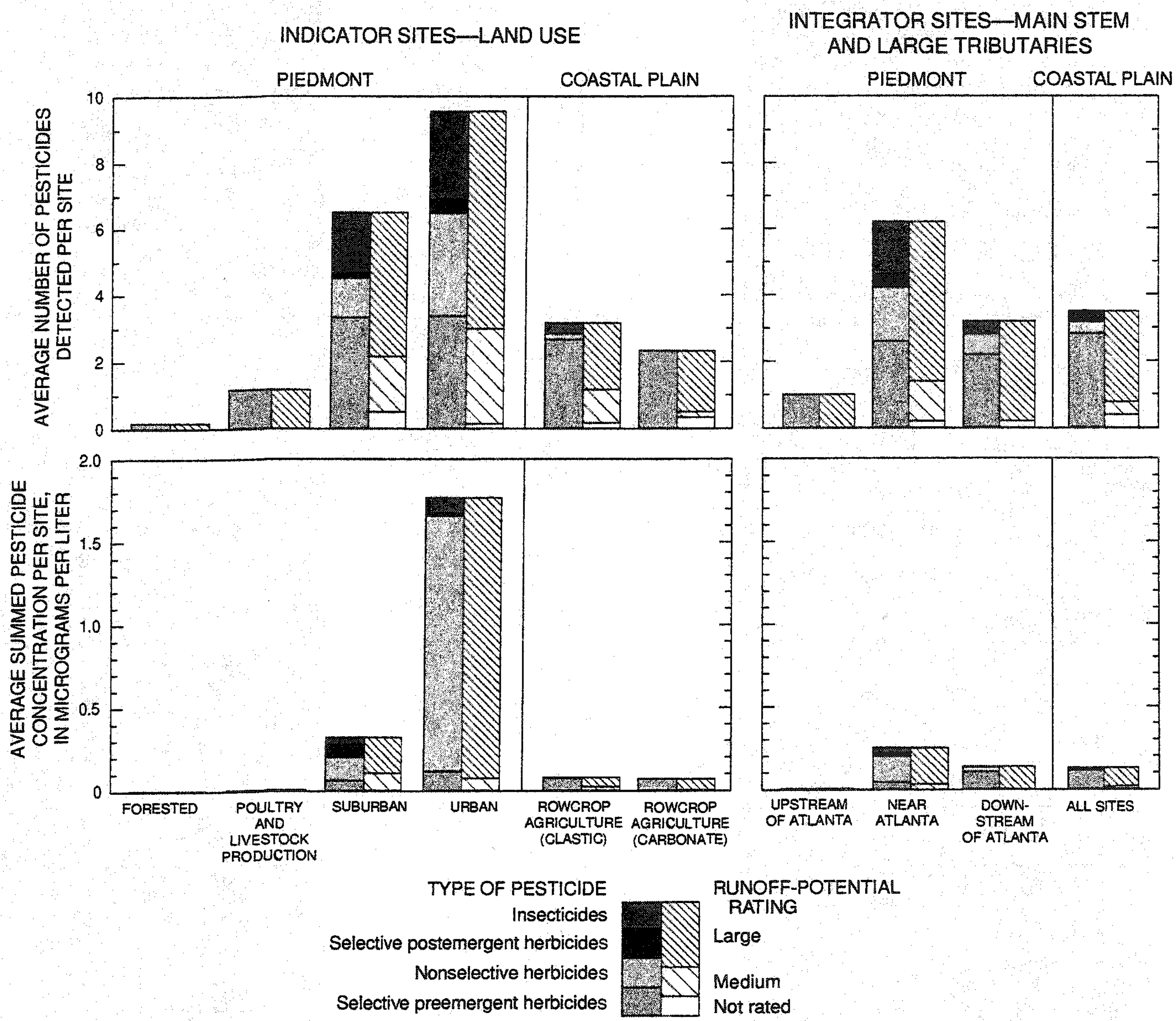

Figure 3. Average number of pesticides detected and summed pesticide concentration per site for samples collected during the May 1994 synoptic survey.

PESTICIDE OCCURRENCE AT INTEGRATOR SITES

A total of 17 compounds were detected in 29 of 30 integrator watersheds (Table 4). Pesticide concentrations in streamwater samples from each integrator site were well below the most restrictive of existing standards and guidelines for lifetime exposure in drinking water (Nowell and Resek, 1994). However, concentrations of one or more insecticides met or exceeded existing standards or guidelines for protection of freshwater aquatic life in streamwater samples from each integrator site located near the Atlanta Metropolitan area; at 1 or 5 sites located in the Piedmont downstream of the Atlanta Metropolitan area; and at 2 of 18 of the most downstream sites located in the Coastal Plain.

Herbicides used for selective preemergent weed control were the most frequently detected among the integrator sites. Atrazine was the most commonly detected compound of this type--it was present in streamwater samples from each of the 12 integrator sites located in the Piedmont and 16 of 18 integrator sites in the Coastal Plain. Simazine and metolachlor also were present at a majority of integrator sites; however, simazine occurred primarily in the Piedmont and metolachlor occurred primarily in the Coastal Plain. Simazine was present in streamwater samples from all integrator sites located in the Piedmont near and downstream of the Atlanta Metropolitan area, but was restricted mostly to mainstem sites in the Coastal Plain.

Metolachlor was detected in streamwater samples from 15 of 18 integrator sites located in the Coastal Plain, but was present in 3 of 12 indicator sites in the Piedmont. Although they were detected in small indicator watersheds (Table 3), the selective preemergent herbicides alachlor, butylate, DCPA, pendimethalin, pronamide, terbacil, and trifluralin, were not detected at integrator sites. The absence of these compounds from integrator sites indicates that their occurrence in streams during baseflow conditions may be localized to certain hydrogeologic settings and land use areas where they are used.

Herbicides used for nonselective vegetation control were detected primarily in streamwater samples from integrator sites located in the Piedmont near and downstream of the Atlanta Metropolitan area. Maximum concentrations of these compounds in streamwater samples from integrator sites in the Piedmont were lower than those at nearby indicator sites that have smaller drainage areas.

Insecticides were detected primarily in streamwater samples from integrator sites located in the Piedmont near and downstream of the Atlanta Metropolitan area. Diazinon, carbaryl, chlorpyrifos, or malathion concentrations exceeded guidelines for protection of freshwater aquatic life in streamwater samples collected at each integrator sites located near the Atlanta Metropolitan area; at one mainstem site located in the Piedmont downstream of the Atlanta Metropolitan area; and at two mainstem sites in the Coastal Plain. Diazinon was the most frequently detected insecticide in streamwater samples from integrator sites. Diazinon was detected in streamwater samples from mainstem and large tributary sites located in the Piedmont, but was only detected at two mainstem sites in the Coastal Plain.

Table 4. Dissolved pesticides present in streamwater samples from integrator sites in the Apalachicola-Chattahoochee-Flint River basin, May 1994
[concentrations are in micrograms per liter; det., detections; max. conc., maximum concentration; <, less than]

Pesticide detected	Piedmont crystalline rocks						Coastal Plain siliciclastic and carbonate sediments	
	Sites upstream of Metropolitan Atlanta area		Sites near Metropolitan Atlanta area		Sites downstream of Metropolitan Atlanta area		All sites	
	det. (%)	max. conc.	det. (%)	max. conc.	det. (%)	max. conc.	det. (%)	max. conc.
Compounds used primarily as selective preemergent herbicides								
Atrazine	0	<.001	100	.048	100	.27	89	.076
Cyanazine	0	<.004	0	<.004	0	<.004	22	.043
Deethylatrazine	0	<.002	20	.002	20	.005	33	.006
Fluometuron	0	<.010	20	.010	0	<.010	6	.010
Metolachlor	50	.002	40	.008	20	.005	83	.034
Metribuzin	0	<.004	20	.019	0	<.004	0	<.004
Simazine	0	<.005	60	.060	80	.10	50	.12
Compounds used primarily as selective postemergent herbicides								
Propanil	0	<.004	0	<.004	0	<.004	6	.004
2,4-D	0	<.023	40	.080	0	<.023	6	.050
Compounds used primarily as nonselective vegetation control herbicides								
Diuron	0	<.012	40	.18	20	.050	0	<.012
Linuron	0	<.002	20	.056	0	<.002	0	<.002
Prometon	0	<.018	80	.036	20	.012	6	.018
Tebuthiuron	0	<.010	40	.11	20	.061	28	.030
Compounds used primarily as insecticides								
Carbaryl	0	<.003	40	.020	0	<.003	6	.067
Chlorpyrifos	0	<.004	20	.009	0	<.004	0	<.004
Diazinon	0	<.002	100	.032	40	.009	11	.008
Malathion	0	<.005	0	<.005	0	<.005	6	.050

RELATION OF PESTICIDE OCCURRENCE TO RUNOFF-POTENTIAL RATINGS

Pesticide runoff-potential ratings have been developed by the U.S. Department of Agriculture to be used for first-approximation comparisons of the water-pollution potential of most pesticides in current use on agricultural land (Goss and Wauchope, 1990). The procedure utilizes a standardized set of chemical properties, and assigns runoff-potential ratings of "small," "medium," or "large" to compounds, based on combinations of water solubility, soil half-life, and organic-carbon partitioning coefficients. Runoff-potential ratings for most pesticides used on agricultural land in the ACF River basin as well as other compounds that were detected during this study are shown in Table 1.

Pesticides with large runoff-potential ratings were the most commonly detected and had the highest average summed concentration in streamwater samples from both indicator and integrator sites (Figure 3). This indicates that pesticides with long soil half-lives, high water solubilities, and low organic-carbon partitioning coefficients were the most prevalent in the ACF River basin during the sampling period. The compounds detected that have large runoff-potential ratings include several of the herbicides used for selective preemergent weed control, all the herbicides used for nonselective weed control, and the insecticide diazinon.

Pesticides having medium runoff-potential ratings were detected primarily in streamwater samples from sites in areas of suburban and urban land use, and from integrator sites located near the Atlanta Metropolitan area. Most of the compounds detected that have medium runoff-potential ratings were for the herbicides pendimethalin and metribuzin (used for selective preemergent weed control), 2,4-D (used for selective postemergent weed control), and the insecticides chlorpyrifos and carbaryl. Although these compounds also are used on agricultural land, they were only rarely detected in streamwater samples from sites located in areas of rowcrop agriculture. The prevalence of these compounds in streams draining suburban and urban areas in the Piedmont Province may be an indication either of (1) increased application rates; or (2) greater runoff-potential ratings in these areas relative to rowcrop agricultural areas in the Coastal Plain Province.

CONCLUSIONS

Pesticides were detected most frequently and at highest concentrations in streamwater samples from indicator sites in urban areas; followed by indicator sites in suburban, rowcrop agriculture, poultry and livestock production, and forested areas. Herbicides were the most widely distributed type of pesticide present in streamwater samples from indicator sites. Herbicides used for selective preemergent weed control were the most widely distributed; however, herbicides used for nonselective weed control were present at higher concentrations.

The insecticides carbaryl, chlorpyrifos, and diazinon were detected with greatest frequency in streamwater samples from (1) indicator sites in areas of urban and suburban land use; and (2) integrator sites located near the Atlanta Metropolitan area, comprising 18 of the 22 sites where insecticide concentrations exceeded existing standards or guidelines for protection of aquatic life were

Pesticides with long soil half-lives, high water solubilities, and low organic-carbon partitioning coefficients are the most prevalent in surface-water resources of the ACF River basin during the streamwater sampling period. The compounds detected that have large runoff-potential ratings include several of the herbicides used for selective preemergent weed control, all the herbicides used for nonselective weed control, and the insecticide diazinon. Pesticides having medium runoff-potential ratings were detected primarily in streamwater samples from sites in areas of suburban and urban land use and integrator sites located nearby the Atlanta Metropolitan area.

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