The Occurrence and Transport of Agricultural Pesticides in the Tuttle Creek Lake-Stream System, Kansas and Nebraska

United States Geological Survey Water-Supply Paper 2419

Prepared in cooperation with the Kansas Department of Health and Environment

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By HUGH E. BEVANS, CARLA HYDE FROMM, and SHARON A. WATKINS

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PLATE

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FIGURES

TABLES

CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
inch	2.54	centimeter
foot	0.3048	meter
mile	1.609	kilometer
square mile	2.590	square kilometer
cubic foot per second	0.02832	cubic meter per second
cubic foot per second per square mile	0.01093	cubic meter per second per square kilometer
acre-foot	1,233	cubic meter
ton	0.9072	megagram
ton per square mile	0.3503	megagram per square kilometer
degree Fahrenheit (°F)	([1])	degree Celsius (°C)

[1]°C = (°F-32)/1.8.

°F = 1.8(°C)+32.

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

The Occurrence and Transport of Agricultural Pesticides in the Tuttle Creek Lake-Stream System, Kansas and Nebraska

By Hugh E. Bevans[1], Carla Hyde Fromm[2], *and* Sharon A. Watkins[1]

Abstract

The occurrence and transport of agricultural pesticides in the Tuttle Creek Lake-stream system, Kansas and Nebraska, were investigated by the U.S. Geological Survey in cooperation with the Kansas Department of Health and Environment. Surface-water samples were analyzed for chlorinated hydrocarbon insecticides (aldrin, chlordane, DDT, dieldrin, endrin, lindane, methoxychlor, and toxaphene), which were not detected during the investigation, and for herbicides (alachlor, atrazine, dacthal, metolachlor, metribuzin, and propachlor), which were all detected except dacthal.

The occurrence of pesticides (primarily in the dissolved state) in surface water was related principally to amounts applied, solubility, and time following application. The soluble herbicides alachlor, atrazine, and metolachlor, which rank in the top 10 in amount applied in the study area, were detected most frequently and in the largest concentrations. Herbicides were not detected in April 1986 when initial surface-water samples were collected, were first detected in May following application, reached peak concentrations in June and July, and declined to less than detection levels at most sites by the end of October. A statistical summary of all surface-water herbicide data (1977–86) for the basin indicated that the median monthly concentration of atrazine was less than the detection level (1.2 micrograms per liter) in April, increased to 3.1 micrograms per liter in May, peaked at 8.4 micrograms per liter in June, then slowly declined to 1.8 micrograms per liter in October. Concentrations of other herbicides varied in a similar manner.

Herbicide loads computed for 1986 indicated that 1.2 tons of alachlor (0.23 percent of amount applied), 19 tons of atrazine (2.2 percent), 2.2 tons of metolachlor (2.7 percent), and 0.40 ton of metribuzin (0.71 percent) were transported from the basin at the Big Blue River near Manhattan, Kansas (downstream from Tuttle Creek Lake). The Big Blue River at Marysville, Kansas (upstream from Tuttle Creek Lake), which drains part of the High Plains aquifer in Nebraska, transported larger loads of herbicides than any other lake tributary stream. However, herbicide delivery ratios (percentage of amount applied) were larger for the smaller tributary streams as a result of factors that cause more surface runoff (for example, more precipitation, increased basin slope, and shale bedrock with shallow clay soil).

INTRODUCTION

The occurrence of agricultural pesticides in surface water is an important water-quality issue in eastern Kansas and other areas where crop production is a principal economic and land-use activity, and where public-water supplies are derived primarily from surface-water resources. The widespread use of pesticides, their relatively frequent detection in surface

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water, and their potentially harmful effects on wildlife and human health at relatively small concentrations have caused them to be considered as some of the most deleterious of the agricultural nonpoint-source contaminants.

Previous investigations of the occurrence and transport of agricultural pesticides have been concerned with small areas. Results of field-dissipation studies indicate that herbicide losses range from 1 to 4 percent and vary with tillage practice and field slope (Hall and others, 1972; Hall, 1974; Ritter and others, 1974; Triplett and others, 1978; Leonard and others, 1979; Rhode and others, 1981; Glotfelty and others, 1984).These studies also indicate that most of the herbicides are transported from fields during runoff that occurs within several weeks after application (Wauchope, 1978; Glotfelty and others, 1984). Clayey soil has been shown to be a contributing factor in herbicide transport (Frank and Sirons, 1979), probably because runoff from this type of soil is greater than from sandy soil. However, little is known about the transport of agricultural pesticides from large drainage areas. Information about the occurrence of pesticides in large multipurpose surface-water bodies (rivers and lakes used for wildlife habitat, recreation, and public-water supplies) is needed to determine if the water quality is adequate for intended uses or if regulatory or remedial actions are needed.

The U.S. Geological Survey, in cooperation with the Kansas Department of Health and Environment, investigated the occurrence and transport of agricultural pesticides in the Tuttle Creek Lake-stream system in Kansas and Nebraska during 1986. The investigation described in this report provided the data and interpretation needed to:

(1) Describe and explain the variation of pesticide concentrations observed in the lake-stream system; and
(2) Describe and develop quantitative estimates of pesticide transport through the lake-stream system.

Purpose and Scope

This report describes and quantifies the occurrence and transport of agricultural pesticides in the Tuttle Creek Lake-stream system. Factors that affect the occurrence and transport of pesticides in surface-water systems are discussed, including environmental characteristics (climate, physiography, and geology) and pesticide properties (solubility, persistence, and quantities applied). Detection frequencies and concentrations for pesticide analyses of surface-water and bed-material samples, collected in the study area during 1969–86, are discussed in relation to human health and freshwater aquatic-life water-quality criteria. The occurrence of pesticides in the system is described with respect to state (dissolved or sorbed to suspended matter), date of application, and response to runoff from precipitation. Budgets of loads transported in the system and delivery ratios (quantity applied divided by load transported) for selected soluble herbicides are computed for subbasins and the system as a whole.

Study Area

The study area is delineated by the drainage basin boundary of the Big Blue River (fig. 1). This 9,640-square-mile area is located in southeast Nebraska (7,200 square miles) and northeast Kansas (2,440 square miles). In addition to the Big Blue River, other major streams in the area include the Little Blue River and the Black Vermillion River.

Tuttle Creek Lake is located on the Big Blue River approximately 10 miles upstream from the confluence of the Big Blue and Kansas Rivers. The lake, which was constructed by the U.S. Army Corps of Engineers and began storing water in 1962, has a total capacity of 3,185,700 acre-feet, which consists of the following: sedimentation pool, 211,500 acre-feet; conservation pool, 177,100 acre-feet; flood-control pool, 1,937,000 acre-feet; and surcharge pool, 860,100 acre-feet. When Tuttle Creek Lake is filled to the elevation of the conservation pool (1,075 feet above sea level), the surface area is approximately 25 square miles, and when it is filled to the elevation of the flood-control pool (1,136 feet above sea level), the surface area is approximately 84 square miles. Although the lake was constructed primarily for flood control, it is used also to maintain streamflow in the Kansas River during low-flow periods and is a potential source of public-water supplies for northeast Kansas.

Data Collection and Analysis

Interpretations developed and presented in this report are based on previously collected data and data collected during this investigation. Previously sampled surface-water sites are shown in figure 1 and listed in Appendix A-1 at the end of this report. Appendix A-1 also presents a summary of available pesticide data, which were obtained from the U.S.

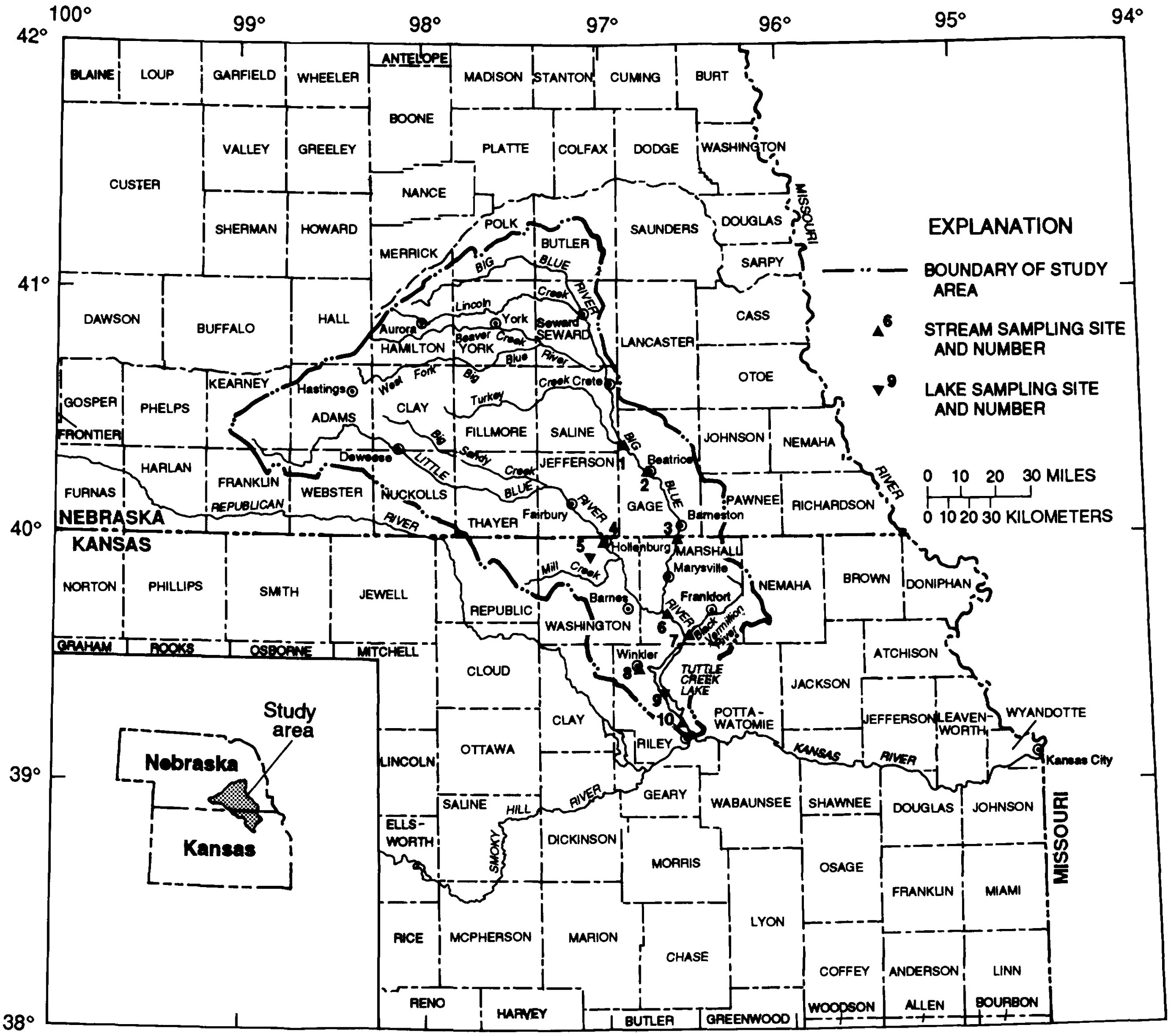


Figure 1. Location and extent of study area and location of previously sampled surface-water sites, 1969–86.

Environmental Protection Agency's STORET data base.

Surface-water sampling sites established for this investigation are shown in figure 2. Data collection began in April 1986 and continued until pesticides were no longer detected in December 1986. Tributary streams to Tuttle Creek Lake (Big Blue River at Marysville, site 11; Little Blue River near Barnes, site 12; Black Vermillion River near Frankfort, site 13; and Fancy Creek at Winkler, Kansas, site 14 in fig. 2) were sampled monthly and during runoff periods. Tuttle Creek Lake sites (sites 15–19 in fig. 2) and the lake outflow (Big Blue River near Manhattan, site 20 in fig. 2) were sampled monthly. All stream sites except Fancy Creek at Winkler (site 14), where daily stream-stage measurements were made by an observer, are U.S. Geological Survey streamflow-gaging stations.

Samples from streams were cross sectionally and depth integrated, and samples from Tuttle Creek Lake were collected primarily at depths of about 1.0 foot. Prior to sampling at lake sites, depth profiles of specific conductance, pH, water temperature, and dissolved oxygen were measured to determine if the lake was stratified. Although stratification was not observed in the lake, water samples occasionally were collected near the lake bottom.

Water samples from all sites were analyzed for total-recoverable pesticides. Additionally, dissolved pesticides were analyzed in filtered (0.2-micrometer

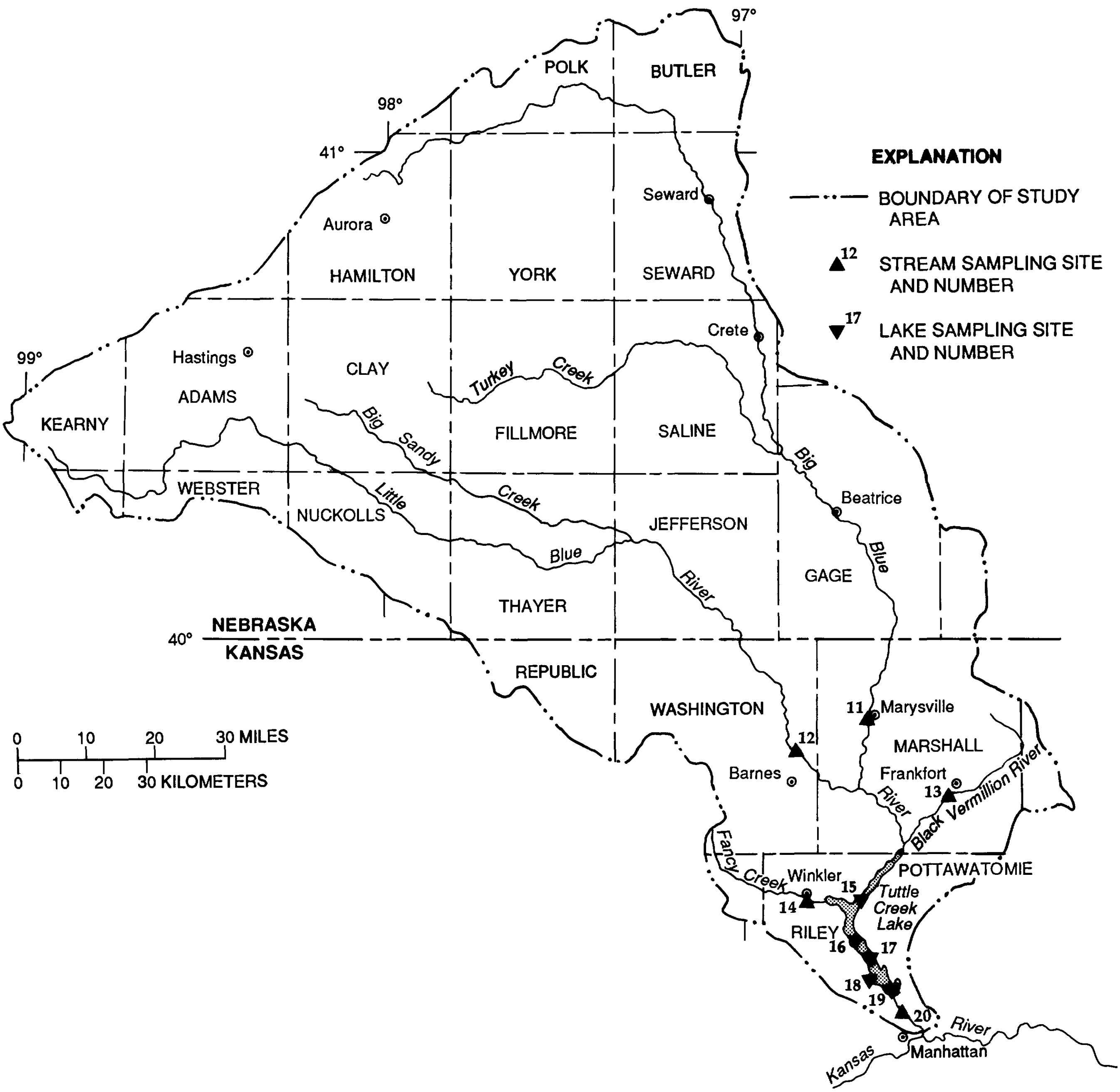


Figure 2. Location of surface-water sites sampled during 1986.

silver filter) water samples from the Big Blue River at Marysville (site 11, fig. 2). All pesticide analyses were performed by the Kansas Department of Health and Environment in Topeka according to U.S. Environmental Protection Agency Method 608 (U.S. Environmental Protection Agency, 1984), using gas chromatography. Pesticide and related data for surface-water sites sampled during this investigation are presented in Appendix A-2 at the end of this report. These data are available from the U.S. Geological Survey Water Data Storage and Retrieval System (WATSTORE) and the U.S. Environmental Protection Agency Storage and Retrieval System (STORET) data bases.

HYDROLOGIC SETTING

The hydrology of the study area generally is determined by climatic, physiographic, and geologic characteristics. Although this investigation was concerned with surface water, geologic characteristics that determine aquifer properties affect low flow and base flow of streams.

The Big Blue River Basin has a humid continental climate. During the summer, the weather is dominated by air masses from the Gulf of Mexico and, as a result, is hot and humid. Winter weather is dominated by cold dry air masses from Canada. Mean annual precipitation from 1951 through 1980 ranged from about 24 inches in the northwest part of the basin to about 32 inches in the southeast part (Stamer and others, 1987). Most of the precipitation occurs as rain during the growing season, approximately May through September. Evapotranspiration rates are large during the growing season and can severely stress crops. During winter, evapotranspiration rates are minimal but so is precipitation. The study area is subject to extreme deviations from average climatic characteristics, and droughts or floods can occur during any season. The largest streamflows and precipitation generally occur in May and June, and the smallest generally occur in December and January. However, rapid rates of evapotranspiration decrease streamflows in July and August, and snowmelt in March causes larger streamflows than would be expected if precipitation were the only factor involved.

Plains with local relief less than 300 feet (Hammond, 1970) generally occur northwest of an imaginary line that dissects the area and runs through Beatrice, Nebraska, and the confluence of Mill Creek and the Little Blue River in Kansas (fig. 1). Southeast of the plains area, the land surface consists of open hills, with as much as 500 feet of local relief. The effects of greater surface relief on streamflow are illustrated by comparing flow-duration curves for the Little Blue River, which drains the plains area, and the Black Vermillion River, which drains the open-hills area (fig. 3). These curves show daily mean streamflows in cubic feet per second per square mile that are equaled or exceeded an indicated percentage of time. Streamflow per square mile is greater in the Black Vermillion River than in the Little Blue River during the percentage of time that streamflow is provided by surface runoff (approximately 50 percent or less) because of greater surface relief and precipitation.

Part of the plains area, northwest of an imaginary line that dissects the area and runs through the confluence of Turkey Creek and the Big Blue River

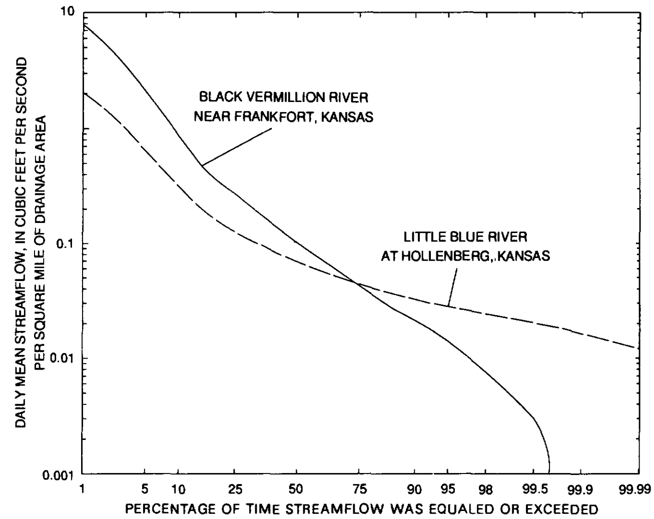


Figure 3. Streamflow-duration curves for Little Blue River at Hollenberg and Black Vermillion River near Frankfort, Kansas, 1974–87.

and the confluence of Big Sandy Creek and the Little Blue River in Nebraska (fig. 1), is underlain by the High Plains aquifer (Ellis and others, 1985), which consists of thick unconsolidated gravel, sand, silt, and clay deposits of Cenozoic age. The remainder of the plains area is underlain by the Great Plains aquifer (Bevans and others, 1985), which consists of the Dakota and Cheyenne Sandstones of Cretaceous age. To the southeast of the imaginary line, the open-hills area is underlain by shale and interbedded limestone of Permian age. The High Plains and Great Plains aquifers discharge substantial quantities of water to streams, whereas Permian rocks discharge very little water to streams. The effect of ground-water discharge on streamflow is illustrated also by comparing flow-duration curves for the Little Blue River, which drains part of the area underlain by the High Plains and Great Plains aquifers, and the Black Vermillion River, which drains part of the area underlain by rocks of Permian age (fig. 3). Streamflow per square mile is greater in the Little Blue River than in the Black Vermillion River during that percentage of time when streamflow is provided by ground-water discharge (approximately 75 percent and greater). Climatic, physiographic, and geologic characteristics not only determine streamflow characteristics but also affect stream transport of agricultural nonpoint-source contaminants.

AGRICULTURAL PESTICIDES

Agricultural pesticides generally include all substances used for preventing, destroying, repelling, or mitigating the effects of insects, nematodes, fungi, weeds, or any other life forms considered as pests. Pesticides that have been analyzed for in surface-water samples from the Big Blue River Basin are listed in Appendices A-1 and A-2 at the end of the report. Although other pesticides, in addition to those listed in Appendices A-1 and A-2, are used in the study area, those listed are representative with respect to properties that determine their occurrence and transport in the hydrologic environment.

Properties and Health Criteria

The occurrence of pesticides in surface water depends primarily on their rate of use and properties that determine how they are transported in the hydrologic environment (solubility) and how long it takes for them to degrade (persistence). Information pertaining to the chemical class, use, solubility, and persistence of agricultural pesticides detected in surface-water or bed-material samples from surface-water sites in the Big Blue River Basin is presented in table 1.

For the most part, chlorinated hydrocarbon insecticides are used infrequently because most of them (all of those listed in table 1) have been suspended, canceled, or restricted by the U.S. Environmental Protection Agency (1985). They are the least-soluble pesticides, ranging from 3.1 micrograms per liter for DDT to 7,870 micrograms per liter for lindane, and the most persistent, ranging from about 3 years for 75 percent of dieldrin and lindane to degrade in the soil to about 5 years for chlordane. These pesticides rarely are detected in surface-water samples (table 2), are transported by water in the suspended state, and tend to accumulate in sediment and biota. Chlordane, DDD, DDE, DDT, and dieldrin, have been detected in both bed-material samples from the Big Blue River Basin (table 2) and in fish-tissue samples of common carp and white bass from Tuttle Creek Lake (Kansas Department of Health and Environment, 1988)

Organophosphate insecticides (table 1) are more soluble, ranging from 24,000 micrograms per liter for parathion to 40,000 micrograms per liter for Diazinon[1], and much less persistent, ranging from 1 week for parathion to 13 weeks for Diazinon, than the chlorinated hydrocarbon insecticides. Organophosphate insecticides probably are transported largely in the dissolved state. However, they degrade rapidly and do not accumulate in sediment or biota. Diazinon was detected more frequently than parathion in surface-water samples (table 2) because it is more soluble and persistent.

Herbicides are relatively soluble, ranging from 70,000 micrograms per liter for atrazine to 1,200,000 micrograms per liter for metribuzin, and persistent, ranging from 1 to 4 weeks for 2,4-D to about 1 year for atrazine (table 1). Alachlor, atrazine, metolachlor, and 2,4-D are used extensively, as they are the only pesticides in table 1 that rank in the top 10 by pounds of active ingredient applied in the lower Kansas River Basin, which includes the Big Blue River Basin (Bevans, 1991). Because of their widespread use, large solubility, and persistence, some herbicides are detected frequently in water samples from the Big Blue River Basin (table 2). Herbicides are transported by water primarily in the dissolved state and probably do not accumulate to any appreciable degree in sediment or biota (Smith and others, 1988). Herbicides that were detected in water samples from the Big Blue River Basin were not detected in fish-tissue samples of common carp and white bass from Tuttle Creek Lake (Kansas Department of Health and Environment, 1988).

Evaluations of water-quality criteria for human health and freshwater aquatic life with respect to detection frequency and maximum concentrations detected in water (table 2) indicate (1) detected concentrations of DDD, DDE, DDT, and dieldrin have equaled or exceeded human-health criteria but probably are not a health concern because of their infrequent detection and because most are no longer used; (2) Diazinon has been detected frequently, and concentrations have exceeded both human-health and freshwater aquatic-life criteria, but only 57 samples have been analyzed; and (3) concentrations of two of the most frequently detected herbicides (alachlor and atrazine) commonly exceeded human-health criteria. The previously collected available data (Appendix A-1 at the end of this report) and the data collected during this investigation (Appendix A-2 at the end of this report) have some deficiencies in that several pesticides (trifluralin, carbofuran, cyanazine, parathion, phorate,

[1]The use of trade names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Table 1. Characteristics of pesticides detected in surface-water or bed-material from surface-water sites in the Big Blue River Basin, 1969–86

[--, ranking of pesticide unknown but not in top 10; >, greater than]

Common name	Chemical name	Chemical class	Use	Ranked by[1] pounds of active ingredients applied in the lower Kansas River Basin (1982)	Solubility in water (micrograms per liter)	Persistence[2] in soil (weeks)
Chlordane[3]	1,2,4,5,6,7,8,8-Octachloro-2, 3,3a,4,7,7a-hexahydro-4,7-methano-1H-indene	Chlorinated hydrocarbon	Insecticide (subterranean termite control)	--	[4]56	[5]260
DDD[3]	1,1-Dichloro, 2,2-bis (p-chlorophenyl) ethane	do.	Insecticide (fruits, vegetables)	--	[4]20	[4]>210
DDE	1,1-Dichloro, 2,2-bis (p-chlorophenyl) ethylene	do.	Degradation product of DDT	--	[4]40	[4]>210
DDT[3]	1,1,1-trichloro, 2,2-bis (p-chlorophenyl) ethane	do.	Insecticide (mosquito control, agriculture)	--	[4]3.1	[5]210
Dieldrin[3]	1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octa-hydro-endo, exo-1,4:5,8-di-methanonaphthalene	do.	Insecticide (soils)	--	[4]195	[5]160
Lindane[3]	Gamma isomer of 1,2,3,4,5,6-hexachlorocyclohexane	Chlorinated hydrocarbon	Insecticide (soils, vegetables, fruits)	--	[4]7,870	[5]160
Diazinon	0,0-diethyl 0-2-isopropyl-4-methyl-6-pyrimidyl thio-phosphate	Organophosphate	Insecticide (soils, fruits, vegetables, forage, field crops, rangeland, house)	--	[4]40,000	[5]13
Parathion	0,0-diethyl 0-p-nitrophenyl phosphorothioate	do.	Insecticide (agricultural crops)	--	[4]24,000	[5]1
2,4-D	(2,4-Dichlorophenoxy) acetic acid	Chlorophenoxy acid	Herbicide (grass, wheat, oats, sorghum, corn)	4	[4]890,000	[6]1-4
2,4,5-T[3]	(2,4,5-trichlorophenoxy) acetic acid	Chlorophenoxy acid	Herbicide (industrial sites and rangeland)	--	[4]278,000	[5]22
Atrazine	2-chloro-4-ethylamino-6-iso-propylamine-s-triazine	Triazine	Herbicide (corn, sorghum)	1	[4]70,000	[6]43-71
Metribuzin	4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4H)-one	do.	Herbicide (soybeans, wheat, alfalfa, fallow land)	--	[7]1,200,000	[6]21-29
Alachlor	2-chloro-2',6'-diethyl-N-(methoxymethyl) acetanilide	Acetanilide	Herbicide (corn, soy-beans)	2	[8]242,000	[6]6-10
Propachlor	2-chloro-N-isopropyl-acetanilide	do.	Herbicide (corn, sor-ghum, soybeans)	--	[8]580,000	[6]4-6
Metolachlor	2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl) acetamide	Acetamide	do.	7	[7]530,000	[9]8-16

[1] Bevans, 1991. The lower Kansas River Basin includes the Big Blue River Basin. Those pesticides ranked 3 (trifluralin), 5 (carboturan), and 6 (cyanazine) either have not been sampled for or have not been detected.
[2] Time required for at least 75 percent of the compound to degrade.
[3] Suspended, canceled, or restricted by the U.S. Environmental Protection Agency (1985).
[4] Smith and others, 1988.
[5] Graham, 1985.
[6] Canter, 1986.
[7] Meister, 1984.
[8] National Academy of Sciences, 1977.
[9] Nilson and others, 1986.

Table 2. Detection frequencies in surface-water and bed-material samples, maximum concentrations detected in surface-water samples, and water-quality criteria for pesticides detected in samples from surface-water sites in the Big Blue River Basin, 1969–86

[--, not determined]

Pesticide	Number of detections (samples): Surface water	Number of detections (samples): Bed material	Maximum concentration detected in surface water (micrograms per liter)	Water-quality criteria (micrograms per liter): Human health	Water-quality criteria (micrograms per liter): Freshwater aquatic life
Chlordane	2(733)	1(28)	0.20	[1]0.027	[2]2.4
DDD	1(148)	4(28)	.84	[2].000024	[2]1.1
DDE	4(158)	4(28)	.17	[2].000024	[2]1.1
DDT	3(740)	5(28)	.90	[2].000024	[2]1.1
Dieldrin	22(732)	3(26)	.04	[1].002	[2]1.0
Lindane	7(740)	1(28)	.19	[1].2	[2]2.0
Diazinon	14(57)	0(0)	1.9	[1].635	[3].009
Parathion	4(54)	0(0)	.03	[4]30	[2].04
2,4-D	53(369)	0(0)	7.0	[1]70	[3]4.0
2,4,5-T	29(355)	0(0)	1.4	[1]21	--
Alachlor	112(419)	0(0)	10	[1].5	--
Atrazine	282(458)	0(0)	51	[1]3	--
Metolachlor	137(313)	0(0)	22	[1]10	--
Metribuzin	55(390)	0(0)	5.6	[1]175	--
Propachlor	20(392)	0(0)	10	[1]92	--

[1] U.S. Environmental Protection Agency, 1987.
[2] U.S. Environmental Protection Agency, 1986.
[3] McNeely and others, 1979.
[4] National Academy of Sciences, 1977.

and carbaryl), which rank in the top 10 herbicides or insecticides applied in the study area (Bevans, 1991), either have not been sampled for, or have not been detected in the few samples that have been collected.

Estimates of Herbicide Application

Estimates of 1986 herbicide (alachlor, atrazine, metolachlor, and metribuzin) application in the Big Blue River Basin are presented in table 3. Estimates for the drainage basins of the Big Blue River at Marysville (site 11, fig. 2), the Little Blue River near Barnes (site 12), the Black Vermillion River near Frankfort (site 13), and Fancy Creek at Winkler (site 14) were developed from information about crop acreages (Conservation Tillage Information Center, 1986a, 1986b), herbicide application rates (Johnson and Kamble, 1984; Harvest Farm Unit, 1986), and active ingredients in herbicides (Kansas State Board of Agriculture, oral commun., 1983; Johnson and Kamble, 1984; Nilson and others, 1986). Herbicide application for the ungaged local drainage area to Tuttle Creek Lake (shown on plate 1) was estimated by determining average application rates in tons per square mile for the Black Vermillion River near Frankfort and Fancy Creek at Winkler tributary basins and multiplying by the ungaged local drainage area (920 square miles). The average application rates for the Black Vermillion River and Fancy Creek were used because their drainage areas are fairly representative of the ungaged local drainage area. Estimates of applications for the Big Blue River near Manhattan were developed by summing the quantities applied in the four tributary basins and the estimates for the ungaged drainage area.

PESTICIDE OCCURRENCE

Water samples from surface-water sites in the Big Blue River Basin (fig. 2) were analyzed for the pesticides listed in Appendix A-2 at the end of the report. Because of the previously discussed pesticide properties and application rates, the only pesticides detected were the soluble herbicides alachlor, atrazine, metolachlor, metribuzin, and propachlor. Propachlor was detected only in water samples from the Black Vermillion River and Fancy Creek, probably because it is the least used and least persistent of these herbicides (table 1).

Although it is known that soluble herbicides are transported primarily in the dissolved state, both

Table 3. Estimated application of alachlor, atrazine, metolachlor, and metribuzin in the Big Blue River Basin, 1986

Drainage basin	State	County	Herbicide applications, in tons[1] Alachlor	Atrazine	Metolachlor	Metribuzin
Big Blue River at Marysville, Kans.	Nebraska	Adams	5.5	7.9	0.45	0.32
		Butler	30	33	2.2	3.9
		Clay	15	25	1.7	.79
		Fillmore	38	51	3.5	4.3
		Gage	36	58	5.6	7.4
		Hamilton	56	70	3.6	3.6
		Jefferson	7.9	17	1.4	.81
		Pawnee	3.4	5.7	.60	.80
		Polk	22	30	1.8	1.9
		Saline	34	44	3.5	5.5
		Seward	32	43	3.4	4.9
		York	61	91	5.6	4.3
	Kansas	Marshall	3.1	9.1	2.9	.68
		Washington	.42	1.3	.39	.07
	Total		**340**	**490**	**37**	**39**
Little Blue River near Barnes, Kans.	Nebraska	Adams	36	51	1.9	1.8
		Clay	19	32	1.1	.90
		Fillmore	13	17	.56	1.3
		Jefferson	11	22	.60	.96
		Kearney	24	34	1.4	.55
		Nuckolls	8.2	22	.55	.84
		Thayer	31	47	1.4	3.18
		Webster	3.3	7.4	.22	.20
	Kansas	Republic	5.4	15	3.4	.51
		Washington	9.2	29	8.4	1.5
	Total		**160**	**280**	**20**	**12**
Black Vermillion River near Frankfort, Kans.	Kansas	Marshall	6.0	18	5.6	1.2
		Nemaha	2.3	7.0	1.9	.30
		Pottawatomie	.04	.10	.02	.01
	Total		**8.3**	**25**	**7.5**	**1.5**
Fancy Creek at Winkler, Kans.	Kansas	Clay	.86	2.6	.72	.12
		Riley	.48	1.4	.41	.08
		Washington	1.1	3.5	1.0	.16
	Total		**2.4**	**7.5**	**2.1**	**.36**
Ungaged local drainage to Tuttle Creek Lake, Kans.	**Total[2]**		**16**	**48**	**14**	**2.8**
Big Blue River near Manhattan, Kans.	**Total[3]**		**530**	**850**	**81**	**56**

[1] All values rounded to two significant figures.
[2] Average herbicide application rate in tons per square mile for the Black Vermillion River near Frankfort and Fancy Creek Basins were determined and multiplied by the ungaged drainage area (920 square miles) to estimate herbicide application.
[3] Totals are sums of totals for the four tributary streams and the ungaged local drainage area.

total-recoverable and dissolved analyses were conducted on water samples from the Big Blue River at Marysville, Kansas. A statistical summary of selected data (concurrent total-recoverable and dissolved values were used if either were detected) shows little difference between concentrations of total-recoverable and dissolved herbicides (table 4). However, total-recoverable concentrations commonly are less than dissolved concentrations, which indicates that extraction efficiencies might be decreased by the presence of suspended sediment.

Total-recoverable concentrations of herbicides detected at surface-water sites sampled during this investigation (Appendix A-2) are plotted on plate 1. Figures representing the four tributary streams and the lake outflow (plate 1) also show the daily mean streamflow. Examination of these graphs indicates that herbicide concentrations in tributary streams vary in response to

Table 4. Total-recoverable and dissolved herbicide concentrations in water samples from the Big Blue River at Marysville, Kansas, 1986[1]

[Concentrations in micrograms per liter; <, less than]

Herbicide	Number of samples	Median concentration	Maximum concentration	Minimum concentration
Alachlor, total recoverable	10	0.42	4.5	<0.25
Alachlor, dissolved	10	.66	4.7	.30
Atrazine, total recoverable	14	5.0	13	1.3
Atrazine, dissolved	14	4.7	12	<2.5
Metolachlor, total recoverable	10	.64	1.6	.33
Metolachlor, dissolved	10	.76	1.3	.28
Metribuzin, total recoverable	8	.19	.32	<.10
Metribuzin, dissolved	8	.26	.68	.19

[1] Only concurrently collected data pairs with herbicide detections were used in these comparisons.

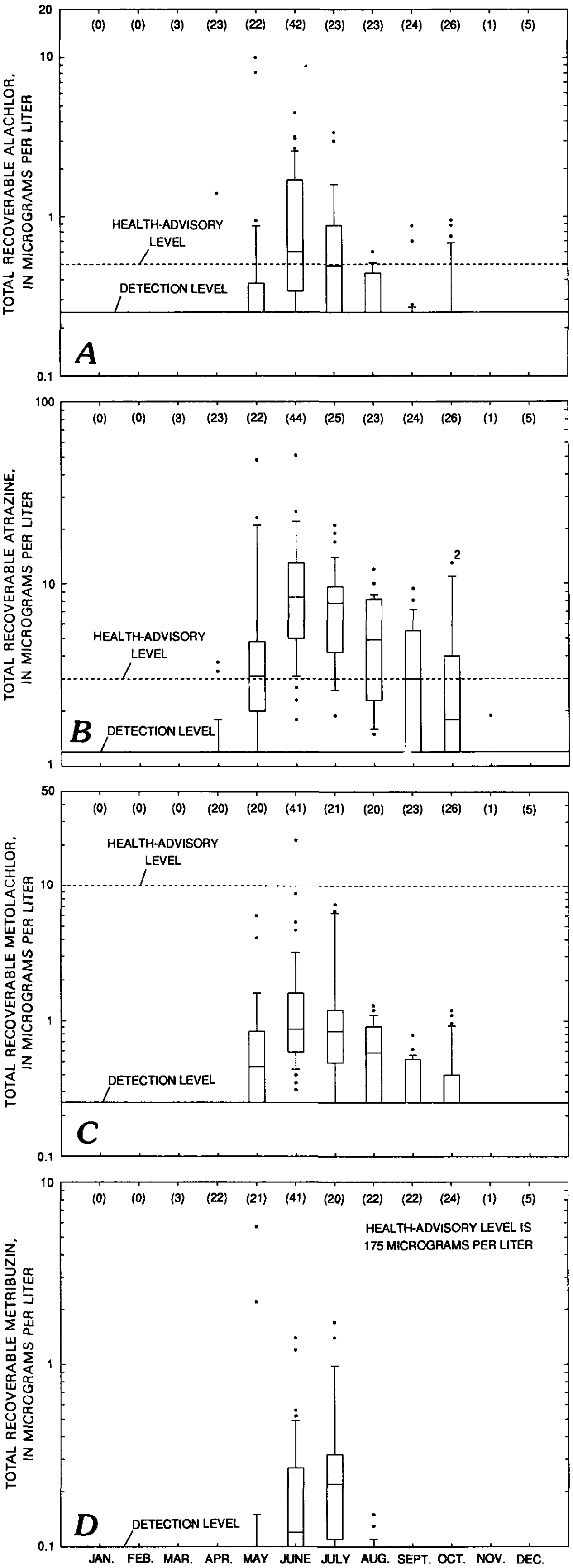
time following application and hydrologic factors (surface runoff and drainage-basin characteristics).

The time dependence of herbicide concentrations can be seen in the relations shown on plate 1. The herbicides are applied for pre-emergent weed control in late winter or early spring. When sites were sampled initially in early April 1986, herbicides were not detected in water samples from the tributary streams or Tuttle Creek Lake. Atrazine (1.6 micrograms per liter) detected in a water sample from the Big Blue River near Manhattan, 2.5 miles downstream from the dam, was either a residual from 1985 application or could have come from a local source. Herbicides probably first entered tributary streams during the large runoff that occurred in late April and early May, as shown in the hydrographs on plate 1. Most herbicides were detected in May, concentrations peaked in June and July, and only atrazine was detected in water samples from tributary streams after July. Atrazine continued to be detected in water samples from at least one tributary stream (Black Vermillion River) until late October. Herbicides generally still were detected in water samples from Tuttle Creek Lake and the Big Blue River near Manhattan (plate 1) after concentrations decreased to less than detection levels in water samples from tributary streams. Water samples occasionally collected near the bottom at lake sites indicated that the lake was vertically mixed with respect to herbicides. Depth profiles of specific conductance, pH, water temperature, and dissolved oxygen collected at each site prior to sampling confirmed that the lake was vertically mixed.

All available data (Appendices A-1 and A-2) for alachlor, atrazine, metolachlor, metribuzin, and propachlor were summarized statistically, and monthly box plots showing the 10th-, 25th-, 50th- (median), 75th-, and 90th-percentile values and values outside this range are presented in figures *4A–4E*. Also shown are the U.S. Environmental Protection Agency health-advisory levels (see table 2) and Kansas Department of Health and Environment detection levels for each herbicide. These figures show the time dependency of herbicide concentrations in surface water, and that alachlor and atrazine concentrations frequently exceeded U.S. Environmental Protection Agency health-advisory levels.

The effect of runoff on instream concentrations of herbicides can be seen on plate 1. The graph of the Big Blue River at Marysville shows that concentrations of alachlor, atrazine, metolachlor, and metribuzin increased on June 5 in response to storm runoff. Increased concentrations also occurred in the Little Blue River at Barnes in response to storm runoff on July 1, in the Black Vermillion River near Frankfort on June 6 and 30, and in Fancy Creek at Winkler on June 5.

The Big and Little Blue River Basins have shallow aquifers that are recharged by precipitation and can contribute soluble herbicides to ground water. Occasionally, storm runoff can dilute instream concentrations of herbicides that are contributed by ground-water discharge. This phenomenon is illustrated on plate 1, which shows that storm runoff in early July probably caused the decreased atrazine concentrations in the Big Blue River at Marysville.



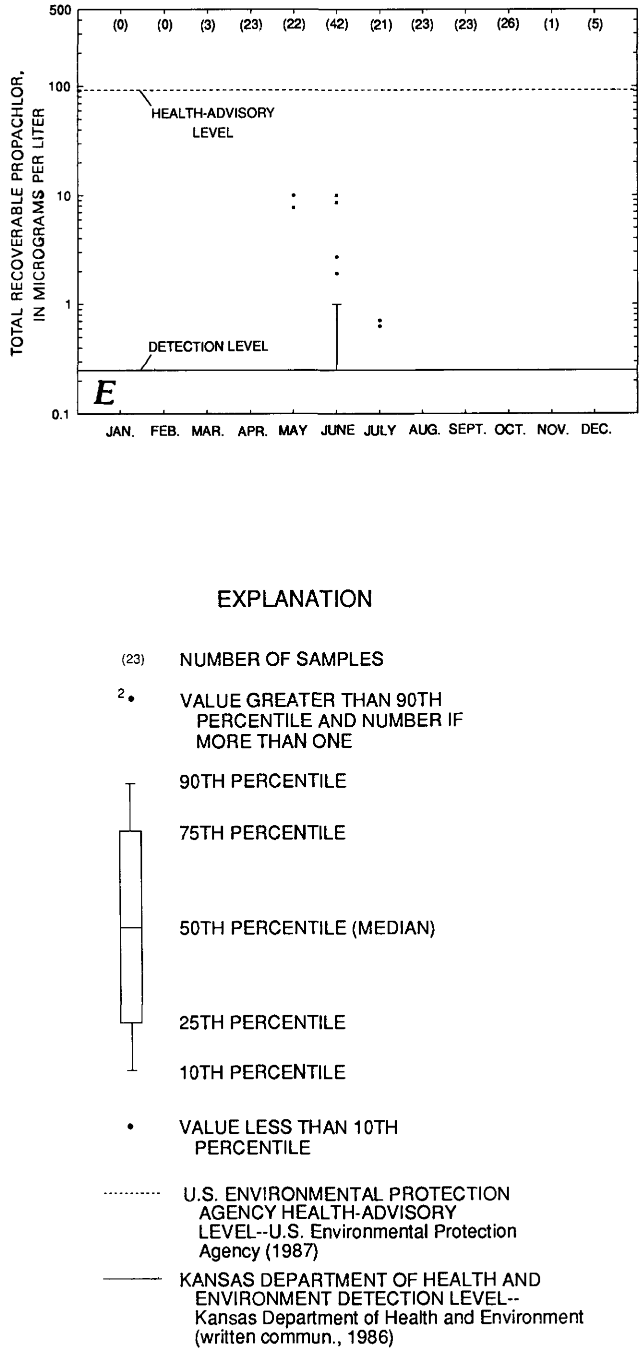


Figure 4. Monthly distribution of total-recoverable concentrations measured at surface-water sites in the Big Blue River Basin during 1977–86, health-advisory levels, and detection levels for (*A*) alachlor, (*B*) atrazine, (*C*) metolachlor, (*D*) metribuzin, and (*E*) propachlor.

Graphs of atrazine concentrations measured in water samples from surface-water sites during 1986 are shown in downstream order in figure 5. The Big Blue River at Marysville had the largest median (50th-percentile) concentration of atrazine. However, the Black Vermillion River and Fancy Creek had the largest concentrations at the 90th percentile. The median concentration of samples from Tuttle Creek Lake was smaller than the median concentration in the Big Blue River at Marysville because of the tributary inflow of smaller median concentrations, particularly from the Little Blue River, and possible degradation of atrazine within the lake. Tuttle Creek Lake's smaller variation in atrazine concentrations, represented by the interquartile range (75th minus 25th percentile), resulted from mixing of large- and small-concentration inflow water during the residence time of water in the lake. The larger median, 25th-, and 75th-percentile concentrations in samples from the Tuttle Creek Lake outflow near Manhattan, compared with concentrations in samples from the lake, resulted not from physical or chemical causes but only from the larger proportion of outflow samples collected in June and July, when concentrations were larger than median, and from a smaller proportion collected in October and December, when concentrations were less than median.

HERBICIDE TRANSPORT

The soluble herbicides detected in samples from surface-water sites in the Big Blue River Basin occurred and were transported primarily in the dissolved state. Calculation of herbicide loads transported in the basin will provide for determination of the herbicide budget, which will give needed insight as to the sources of the herbicides delivered to Tuttle Creek Lake and help to identify causal factors.

Herbicide Budget For Tuttle Creek Lake-Stream System

Censored data (those values reported as less than the detection level) were not used in the procedures for estimating herbicide loads in this report. Most of the censored data were reported for analyses of water samples collected prior to the application of herbicides or after most of the herbicides had been transported from the basins. Herbicide loads were estimated for the general time period during which the herbicides were detected, as shown on plate 1.

Instantaneous loads of herbicides for tributary streams, in tons per day, were computed by multiplying the measured concentration, in micrograms per liter, by the instantaneous streamflow, in cubic feet per

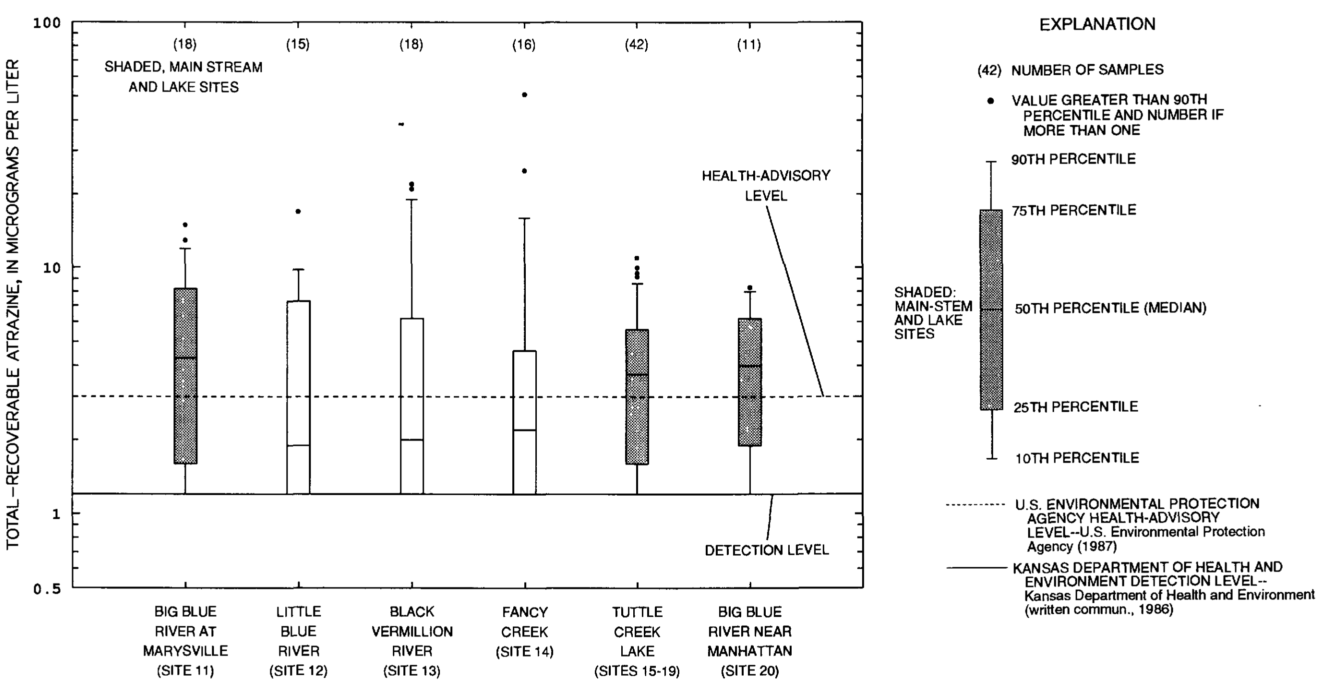


Figure 5. Distribution of total-recoverable atrazine concentrations measured in water samples from surface-water sites in downstream order in Big Blue River Basin, April–December 1986.

second, and by the factor 0.0000027. However, to develop a load budget, it is necessary to estimate loads for those days when water-quality samples for herbicide analysis were not collected. The preferred method for estimating daily loads is to develop a relation between the constituent concentration and one or more known independent variables, such as streamflow. Results of a correlation analysis showed that relations among herbicide concentrations and the independent variables streamflow, cumulative streamflow after herbicide application, and tons of herbicide applied were not significant (p>0.05) for individual tributary stream sites. Because of the few data available for each site, the independent variables were normalized by dividing each by the drainage area, in square miles. Also, data from all tributary stream sites were aggregated for correlation analysis. Results of the correlation analysis showed that herbicide concentrations were not significantly correlated with any of the independent variables. Therefore, daily herbicide concentrations could not be estimated from relations with known independent variables.

It is acceptable to use relations between instantaneous loads of herbicides and instantaneous streamflow to estimate loads of herbicides for days when samples were not collected, although load is a function of streamflow. The dependent (herbicide load) and independent (streamflow) variables were normalized by dividing all values by drainage area, in square miles. The results of a Kruskal-Wallis test (Hollander and Wolfe, 1973) indicated that the normalized dependent and independent variables did not vary among tributary streams sites (p>0.05), thereby justifying the aggregation of data. The nonparametric Kruskal-Wallis test performs a one-way analysis of variance on rank sums. Although the normalized variables did not vary significantly among tributary stream sites, it was hypothesized that they would vary with time due to seasonal climate differences (especially precipitation) and because the soluble herbicides are applied only in early spring as pre-emergent weed control. The results of a Kruskal-Wallis test confirmed (p<0.05) that the normalized variables were significantly different for the time periods May, June, July, and August–October. A Kruskal-Wallis test then was applied to determine if there were differences among tributary stream sites within each period. Results of this test (p>0.05) indicated that the normalized variables did not vary significantly among sites within each time period. Therefore, it was determined that it is appropriate to attempt to develop relations between aggregated herbicide loads, in tons per day per square mile, and streamflow, in cubic feet per second per square mile, for each time period.

Analysis of covariance (ANCOVA) is a technique frequently used to develop statistical models involving both numeric and class variables. Because time period was being used as a class variable in the proposed models (that is, because data for each time period were being grouped), ANCOVA was an appropriate choice for analysis. A model for each of the four time periods (May, June, July, and August–October) was developed to estimate herbicide loads, in tons per day per square mile, from streamflow, in cubic feet per second per square mile. Although these models were highly significant (p<0.0001) and explained most of the variability in herbicide loads, they projected negative loads at low rates of streamflow, a physical impossibility. To avoid this, the data were converted to natural logarithms, and analysis of covariance was used to develop new models. A consequence of log transformations is that the distribution of the dependent variable, conditional on the independent variable, is log normal instead of normal and the mean is not equal to the median (Helsel and Hirsch, 1992).

The mean loads of herbicides at tributary stream sites can be estimated by computing the mean load for short time periods using equations derived by regression analysis and summing the short-term loads for the period of interest. However, simply transforming estimates from a log-log regression equation to the original load units (tons per day per square mile) provides an estimate of the median, not the mean (Helsel and Hirsch, 1992). The median of such a transformed variable is biased low when used as an estimate of the mean because the dependent variable has a definite limit on the smallest value but no limit or a very high limit on the largest value. A nonparametric smearing estimate (Helsel and Hirsch, 1992) can be used to correct for this bias if the relation between the dependent and independent variables is homoscedastic and residuals of the dependent variable are not related to the independent variable. The residuals from the log-log regression equation are exponentiated (converted from logarithms to arithmetic values), and their mean is computed. This mean is the bias-correction factor by which the values (medians) of herbicides loads projected by the log-log regression equation are multiplied. Plots of logarithms of herbicide loads against logarithms of streamflow indicated that the requirement of homoscedasticity was met by the data, and plots of logarithms of residual herbicide loads against logarithms of streamflow indicated they were not related. Therefore, time-period equations and bias-correction factors were developed to estimate daily herbicide loads per square mile from daily mean streamflow in cubic feet per square mile. These time-period equations (in exponential form) and their bias-correction factors, standard errors of estimate, and R^2 values are given in table 5. These equations were highly significant ($p<0.0001$) and explained most of the variation in herbicide loads (R^2 ranged from 0.83 for alachlor and metolachlor to 0.90 for atrazine).

Herbicides were not detected in tributary streams in early April when water samples were first collected but were detected in mid-May when water samples were collected for the second time. These herbicides are applied as pre-emergent weed control in the late winter and early spring and probably were being applied during the relatively dry period that occurred in April, as evidence by the lack of runoff shown on plate 1 hydrographs. Herbicides probably entered tributary streams during the runoff that occurred in late April and early May; they were detected in Tuttle Creek Lake in early May. Therefore, the regression models were used to compute daily herbicide loads beginning on April 27 for the Little Blue River near Barnes and the Big Blue River at Marysville, on May 7 for the Black Vermillion River near Frankfort, and on May 9 for Fancy Creek at Winkler.

Alachlor, metolachlor, and metribuzin were not detected in tributary streams after July; loads of these herbicides were computed through July 30. Atrazine was detected in October, and atrazine loads were computed through October 31. Herbicide loads computed using the equations in table 5 are expressed in tons per day per square mile. Daily loads computed by using these equations must be multiplied by the indicated bias-correction factor, summed, and multiplied by drainage area to compute total load in tons.

Herbicide loads transported by the Big Blue River near Manhattan (downstream from the outfall of Tuttle Creek Lake) were estimated by a different method. Concentrations of herbicides in the lake outfall are not subject to the short-term variations caused by runoff that occurs in the tributary streams (see plate 1) but form smooth distribution curves from their first detections in early May and June until they were no longer detected in August and September.

Herbicide concentrations measured in the sample collected on June 18 were not considered in drawing the concentration curves on plate 1. Water was not being released from Tuttle Creek Lake when the sample was collected. Streamflow in the Big Blue River near Manhattan (36 cubic feet per second) was probably due to the release of water from bank storage and/or discharge of local ground or surface water, and the herbicide concentrations are not representative of lake outflow.

Table 5. Regression models relating loads of herbicides to streamflow for tributary streams in the Big Blue River Basin

[*ALLM2*, alachlor in tons per day per square mile; *ATLM2*, Atrazine in tons per day per square mile; *MRLM2*, metolachlor in tons per day per square mile; *MNLM2*, metribuzin in tons per day per square mile; and *QM2*, streamflow in cubic feet per square mile; all models are significant at the $p = 0.0001$ level]

Herbicide	Time period	Model[1]	Bias-correction factor[2]	R^2	Standard error of estimate in percent below and above regression line	
Alachlor	May	$ALLM2=1.1960X10^{-06}\ QM2^{1.0337}$	1.3926	0.83	-58	137
	June	$ALLM2=2.3991x10^{-06}\ QM2^{1.0337}$	1.3926	.83	-58	137
	July	$ALLM2=3.0951x10^{-06}\ QM2^{0.6325}$	1.3926	.83	-58	137
Atrazine	May	$ATLM2=8.7107x10^{-06}\ QM2^{0.8981}$	1.2217	.90	-50	99
	June	$ATLM2=2.84131x10^{-05}\ QM2^{1.1352}$	1.2217	.90	-50	99
	July	$ATLM2=1.7641x10^{-05}\ QM2^{1.2116}$	1.2217	.90	-50	99
	August - October	$ATLM2=4.5792x10^{-06}\ QM2^{1.1034}$	1.2217	.90	-50	99
Metolachlor	May	$MRLM2=2.8411x10^{-06}\ QM2^{0.7220}$	1.8640	.83	-64	177
	June	$MRLM2=3.5353x10^{-06}\ QM2^{1.1754}$	1.8640	.83	-64	177
	July	$MRLM2=3.3170x10^{-06}\ QM2^{0.9904}$	1.8640	.83	-64	177
Metribuzin	May	$MNLM2=2.8308x10^{-07}\ QM2^{1.0850}$	1.3344	.87	-57	130
	June	$MNLM2=8.5976x10^{-07}\ QM2^{1.0850}$	1.3344	.87	-57	130
	July	$MNLM2=1.1933x10^{-06}\ QM2^{1.0294}$	1.3344	.87	-57	130

[1] Log-log model converted to exponential form to simplify computations.
[2] Daily herbicide load must be multiplied by this factor.

Herbicides first entered Tuttle Creek Lake in late April and early May as a result of the runoff shown in stream hydrographs on plate 1; herbicides were detected in Tuttle Creek Lake in early May. In response to increased inflows to Tuttle Creek Lake that occurred as a result of the late April and early May runoff, outflow from the lake was increased on May 3. This date was selected as the beginning for the occurrence of herbicides in the lake outflow, and herbicide concentrations were set at one order of magnitude less than their detection levels. After herbicides were no longer detected in the lake outfall, August for alachlor and metribuzin and September for atrazine and metolachlor, the curves were extrapolated through time to concentrations that were one order of magnitude less than the detection levels. Concentration curves were used to estimate daily lake-outfall concentrations for

alachlor (May 3–October 4),
atrazine (May 3–November 30),
metolachlor (May 3–November 5), and
metribuzin (May 3–September 10).

These concentrations, in micrograms per liter, were multiplied by daily mean streamflow for the Big Blue River near Manhattan, in cubic feet per second, and by the factor 0.0000027 to compute daily loads in tons. Daily loads were summed to estimate herbicide transport from the Big Blue Basin.

Estimated loads of alachlor, atrazine, metolachlor, and metribuzin transported into Tuttle Creek Lake by the Big Blue River, Little Blue River, Black Vermillion River, and Fancy Creek, and estimated loads transported from Tuttle Creek Lake in the Big Blue River near Manhattan, Kansas, are presented in table 6. Loads computed for Fancy Creek at Winkler probably are least accurate because of the great variability in concentrations and a relatively poor streamflow record (based on daily stream-stage measurements by a local observer).

The basin yielded 1.2 tons of alachlor, 19 tons of atrazine, 2.2 tons of metolachlor, and 0.40 ton of metribuzin during May–October 1986, based on load computed for the Big Blue River near Manhattan, Kansas. The Big Blue River transported the largest loads of herbicides into Tuttle Creek Lake, nearly twice as much as the other three tributary streams combined. The computations indicated much more atrazine load was transported from the Tuttle Creek Lake than transported into the lake by the four tributary streams sampled. Differences in loads transported into and out of the lake probably are due to

Table 6. Estimates of herbicide loads transported by streams, May through October 1986, and delivery ratios for stream subbasins in the Big Blue River Basin, 1986

Stream subbasin	Drainage area, in square miles	Herbicide application, in tons (table 3)				Herbicide load transport by streams, in tons[1] (delivery ratio, in percent of application)			
		Alachlor	Atrazine	Metolachlor	Metribuzin	Alachlor	Atrazine	Metolachlor	Metribuzin
Big Blue River at Marysville, Kans.	4,777	340	490	37	39	0.9 (0.28)	10 (2.0)	2.1 (5.7)	0.48 (1.2)
Little Blue River near Barnes, Kans.	3,324	160	280	20	12	.3 (0.21)	2.7 (0.96)	.56 (2.8)	.09 (0.75)
Black Vermillion River near Frankfort, Kans.	410	8.3	25	7.5	1.5	.10 (1.2)	.83 (3.3)	.18 (2.4)	.03 (2.0)
Fancy Creek at Winkler, Kans.	174	2.4	7.5	2.1	.36	.07 (2.9)	1.1 (15)	.18 (8.6)	.04 (11)
Ungaged local drainage to Tuttle Creek Lake, Kans.[2]	920	16	48	14	2.8	--	--	--	--
Big Blue River near Manhattan, Kans.[3]	9,640	530	850	81	56	1.2 (0.23)	19 (2.2)	2.2 (2.7)	0.40 (0.71)

[1] All values rounded to two significant figures.
[2] Drainage area computed by subtracting drainage areas of the four tributary streams and the surface area of Tuttle Creek Lake, at the conservation-pool elevation, from the drainage area of Tuttle Creek Lake. Herbicide application in the ungaged area estimated by multiplying average herbicide application rates (per square mile) for the Black Vermillion River near Frankfort and Fancy Creek at Winkler basins times the ungaged drainage area.
[3] Herbicide applications were computed by summing herbicide application of Big Blue River at Marysville, Little Blue River near Barnes, Black Vermillion River near Frankfort, Fancy Creek at Winkler, and the ungaged local drainage to Tuttle Creek Lake.

a combination of the following factors: (1) uncertainties in load computations (as indicated by standard error of estimates presented in table 5), (2) herbicides transported from 920 square miles of ungaged and unsampled contributing drainage area adjacent to the lake, and (3) degradation processes occurring during transport and storage in the lake.

Herbicide Delivery Ratios

Herbicide delivery ratios are equivalent to the amount of the herbicide transported by streamflow divided by the amount of the herbicide applied to the drainage area, expressed as a percentage. Herbicide delivery ratios for the Big Blue River near Manhattan (table 6) range from 0.23 percent for alachlor to 2.7 percent for metolachlor. Delivery ratios for soluble herbicides have been shown to increase with increasing basin slope (Wauchope, 1978). This phenomenon is observed in the delivery ratios presented in table 6. Basin slopes are relatively flat for the Big Blue River at Marysville and the Little Blue River near Barnes, which drain large plains areas in Nebraska, but are increasingly steep for the Black Vermillion River near Frankfort and Fancy Creek at Winkler, which drain smaller hilly areas in Kansas. Atrazine delivery ratios generally increase as basin slope increases, from 0.96 percent for the Little Blue River near Barnes and 2.0 percent for the Big Blue River at Marysville, to 3.3 percent for the Black Vermillion River near Frankfort, and 15 percent for Fancy Creek at Winkler. Delivery ratios for alachlor, metolachlor, and metribuzin increase similarly. A previous investigation determined that there was an inverse relation between the concentration of a herbicide measured in runoff and its solubility (Wauchope, 1978). Although results of this study were not entirely consistent with an inverse relation, one item of consistency was that atrazine, the least soluble of these herbicides, had the largest or second largest delivery ratio at each site.

SUMMARY

Available pesticide analyses for surface-water samples from the U.S. Environmental Protection Agency's STORET data base were used in conjunction with analyses of samples collected during this investigation (April–December 1986) to describe the occurrence and transport of agricultural pesticides in surface water of the Tuttle Creek Lake-stream system, Kansas and Nebraska.

Climate, physiography, and geology of the Big Blue River Basin not only determine the hydrology of the area but also are important factors affecting the occurrence and transport of pesticides. The Big and Little Blue Rivers drain plains areas in Nebraska where annual precipitation is about 24 inches. The plains areas have sandy soils and are underlain by thick deposits of clay, silt, sand, and gravel that form the High Plains aquifer and consolidated sandstone that forms the Great Plains aquifer. The Black Vermillion River, Fancy Creek, and local tributaries to Tuttle Creek Lake drain hilly areas with clay soils that are underlain by Permian shale and where annual precipitation exceeds 30 inches. Consequently, runoff per square mile is much greater during low flow in the Big and Little Blue Rivers because of ground-water discharge from the High Plains and Great Plains aquifers, but runoff is much greater during high flow in the Black Vermillion River, Fancy Creek, and local tributaries to Tuttle Creek Lake because of greater precipitation, greater basin slope, clay soil, and shale bedrock (which inhibits infiltration).

The principal factors affecting the occurrence of pesticides in surface water are usage and pesticide characteristics (principally solubility). Chlorinated hydrocarbon insecticides (chlordane, DDD, DDT, dieldrin, and lindane) have been detected in water and bed-material samples from surface-water sites in the Big Blue River Basin but not during this investigation. The use of these insecticides has been suspended, canceled, or restricted by the U.S. Environmental Protection Agency; they are relatively insoluble, occur in and are transported by water in the suspended state, and tend to accumulate in sediment and aquatic biota. Organophosphate insecticides (Diazinon and parathion) have been detected in the basin but were not analyzed for during this investigation. Diazinon and parathion are used infrequently for agricultural application in the basin but are relatively soluble, can be transported both in the dissolved and suspended states, and generally do not accumulate in sediment or biota. Herbicides (alachlor, atrazine, metolachlor, metribuzin, propachlor, 2,4-D, and 2,4,5-T) have been detected relatively frequently in the basin. The chlorophenoxy acid herbicides (2,4-D and 2,4,5-T) were not analyzed for during this investigation. However, the herbicides alachlor, atrazine, and metolachlor, which were detected frequently during

this investigation, are in the top 10 of pesticides applied in the study area, are very soluble, occur and are transported in the dissolved state, and do not accumulate in sediment or biota.

Soluble herbicides were not detected in water samples collected during April (prior to their application), reached peak concentrations in June and July (soon after application), and only atrazine was detected in water samples from tributary streams after July. Atrazine continued to be detected in water samples from the Black Vermillion River until late October. Herbicides generally still were detected in water samples from Tuttle Creek Lake and the Big Blue River near Manhattan (downstream from Tuttle Creek Lake) after they reached less than detection levels in water samples from tributary streams. Median concentrations of alachlor in surface-water samples (1977–86) exceeded the health-advisory level (0.50 microgram per liter) during June and approached it during July. Median concentrations of atrazine in surface-water samples (1977–86) equaled or exceeded the U.S. Environmental Protection Agency health-advisory level (3.0 micrograms per liter) during May through September.

The occurrence of herbicides in Tuttle Creek Lake through time is similar to their occurrence in streams, except there is a slight time lag and the variation in concentrations is much less. During 1986, herbicides entered the upper reaches of the lake soon after application in late spring and early summer, moved though the lake, and were no longer detected in the lake outflow by late October. The lake was well mixed vertically with respect to herbicides.

Herbicide application in the Big Blue River Basin during 1986 was estimated for alachlor (530 tons), atrazine (850 tons), metolachlor (81 tons), and metribuzin (56 tons). Herbicide transport during May–October 1986 from the Big Blue River Basin was determined for alachlor (1.2 tons), atrazine (19 tons), metolachlor (2.2 tons), and metribuzin (0.40 ton). Atrazine delivery ratios (tons transported divided by tons applied times 100) for tributary streams were 2.0 percent for the Big Blue River at Marysville, 0.96 percent for the Little Blue River near Barnes, 3.3 percent for the Black Vermillion River near Frankfort, and 15 percent for Fancy Creek at Winkler. These delivery ratios increased in response to increasing surface runoff (due to increasing precipitation and basin slope, impermeable clay soils and shale bedrock) in the Black Vermillion and Fancy Creek drainage basins. Delivery ratios for other herbicides increased in a similar manner. Delivery ratios for the Big Blue River at Manhattan were alachlor, 0.23 percent; atrazine, 2.2 percent; metolachlor, 2.7 percent; and, metribuzin, 0.71 percent. The Big Blue River at Marysville transported the largest load of atrazine observed for any tributary stream (10 tons).

REFERENCES CITED

Bevans, H.E., 1991, Pesticides and other synthetic-organic compounds, *in* Jordan, P.R., and Stamer, J.K., eds., Surface water-quality assessment of the lower Kansas River Basin, Kansas and Nebraska—Analysis of available data through 1986: U.S. Geological Survey Open-File Report 91–75, p. 138–151.

Bevans, H.E., Spruill, T.B., and Kenny, J.F., 1985, Kansas ground-water resources, *in* U.S. Geological Survey, National water summary 1984—Hydrologic events, selected water-quality trends, and ground-water resources: U.S. Geological Survey Water-Supply Paper 2275, p. 217–222.

Canter, L.W., 1986, Environmental impacts of agricultural production activities: Chelsea, Michigan, Lewis Publishers, Inc., p. 145–148.

Conservation Tillage Information Center, 1986a, 1986 National survey of conservation tillage practices, Nebraska county survey: Fort Wayne, Indiana, National Association of Conservation Districts, Conservation Tillage Information Center, 34 p.

———1986b, 1986 National survey of conservation tillage practices, Kansas county summary: Fort Wayne, Indiana, National Association of Conservation Districts, Conservation Tillage Information Center, 47 p.

Ellis, M.J., Engberg, R.A., Kastner, W.M., and Steele, E.K., Jr., 1985, Nebraska ground-water resources, *in* U.S. Geological Survey, National water summary 1984—Hydrologic events, selected water-quality trends, and ground-water resources: U.S. Geological Survey Water-Supply Paper 2275, p. 291–296.

Frank, R., and Sirons, G.J., 1979, Atrazine—Its use in corn production and its losses to stream waters in southern Ontario, 1975–77: Science of Total Environment, v. 12, p. 223–229.

Glotfelty, D.E., Taylor, A.W., Isensee, A.R., Jersey, J., and Glen, S., 1984, Atrazine and simazine movement to Wye River estuary: Journal of Environmental Quality, v. 13, no. 1, p. 115–121.

Graham, R.J., ed., 1985, Agriculture and groundwater quality: Ames, Iowa, Council for Agricultural Science and Technology Report No. 103, 43 p.

Hall, J.K., 1974, Erosion losses of s-triazine herbicides: Journal of Environmental Quality, v. 3, no. 2, p. 174–180.

Hall, J.K., Pawlus, M., and Higgins, E.R., 1972, Losses of atrazine in runoff water and soil sediment: Journal of Environmental Quality, v. 1, no. 2, p. 172–176.

Hammond, E.H., 1970, Classes of land-surface form: U.S. Geological Survey National Atlas of the United States, p. 61–64.

Harvest Farm Unit, 1986, 1986 agricultural chemicals, crop section—An agricultural chemical survey of subscribers: Kansas Farmer, p. K4.

Helsel, D.R., and Hirsch, R.M., 1992, Statistical methods in water resources: Amsterdam, Netherlands, Elsevier Science Publishers, p. 257–260.

Hollander, M., and Wolfe, D.A., 1973, Nonparametric statistical methods: New York, John Wiley and Sons Publishers, p. 115–119.

Johnson, B.B., and Kamble, S.T., 1984, Pesticide use on major crops in Nebraska—1982: Lincoln, University of Nebraska, Institute of Agriculture and Natural Resources, p. 6, 7, 21–23.

Kansas Department of Health and Environment, 1988, A survey of pesticides in Tuttle Creek Lake, its tributaries and the upper Kansas River: Topeka, Kansas Department of Health and Environment, 29 p.

Leonard, R.A., Langdale, G.W., and Fleming, W.G., 1979, Herbicide runoff from upland Piedmont watersheds—Data and implications for modeling pesticide transport: Journal of Environmental Quality, v. 8, no. 2, p. 223–229.

McNeely, R.N., Neimanis, V.P., and Dwyers, L., 1979, Water quality sourcebook—A guide to water quality parameters: Ottawa, Canada, Inland Waters Directorate, Water Quality Branch, p. 35–36.

Meister, R.T., ed., 1984, Farm chemicals handbook: Willoughby, Ohio, Meister Publishing Co., p. C3–C252.

National Academy of Sciences, 1977, Drinking water and health: Washington, D.C., National Academy of Sciences, Safe Drinking Water Committee, 939 p.

Nilson, E.B., Russ, O.G., Brotemarkle, J.K., Fick, W.H., Kuhlman, D.K., and Ohlenbusch, P.D., 1986, Chemical weed control for field crops, pastures, rangeland, and noncropland: Manhattan, Kansas State University Agricultural Experiment Station Report of Progess 487, 5 p.

Rhode, W.A., Asmussen, L.E., Hauser, E.W., Hester, M.L., and Allison, H.D., 1981, Atrazine persistence in soil and transport in surface and subsurface runoff from plots in the Coastal Plain of the southern United States: Agro-Ecosystems, v. 7, p. 225–238.

Ritter, W.R., Johnson, H.P., Lovely, W.G., and Molnau, M., 1974, Atrazine, propachlor, and diazinon residues on small agricultural watersheds—Runoff losses, persistence, and movement: Environmental Science and Technology, v. 8, p. 38–42.

Smith, J.A., Witkowski, P.J., and Fusillo, T.V., 1988, Manmade organic compounds in the surface waters of the United States—A review of current understanding: U.S. Geological Survey Circular 1007, 92 p.

Stamer, J.K., Jordan, P.R., Engberg, R.A., and Dugan, J.T., 1987, Surface water-quality assessment of the lower Kansas River basin, Kansas and Nebraska: U.S. Geological Survey Open-File Report 87–105, 36 p.

Triplett, G.B., Jr., Conner, B.J., and Edwards, W.M., 1978, Transport of atrazine and simazine in runoff from conventional and no-tillage corn: Journal of Environmental Quality, v. 7, no. 1, p. 71–84.

U.S. Environmental Protection Agency, 1984, Method 608: Code of Federal Regulations, v. 49, no. 209, p. 89–104.

———1985, Suspended, canceled, and restricted pesticides: Washington, D.C., U.S. Environmental Protection Agency Office of Pesticides and Toxic Substances Compliance and Monitoring Staff (EN-342) Booklet, 29 p.

———1986, Quality criteria for water 1986: Washington, D.C., Office of Water Regulations and Standards, EPA 440/5-86-001, unnumbered pages.

———1987, Health advisory summary table: Washington, D.C., Office of Drinking Water.

Wauchope, R.D., 1978, The pesticide content of surface water drainage from agricultural fields—A review: Journal of Environmental Quality, v. 7, no. 4, p. 459–472.

APPENDIX A—HYDROLOGIC DATA

Appendix A-1. Summary of pesticide data for previously sampled surface-water sites in the Big Blue River Basin, 1969–86

Map index number (fig. 1)	Site name	Drainage area (square miles)	Data-collection agency	Period of record	Pesticide analyses	Results (concentrations given in micrograms per liter, µg/L, or micrograms per kilogram, µg/kg)
1	Big Blue River near Pickrell, Nebr.	3,600	NDEC[1]	1985	Alachlor, atrazine, metolachlor, metribuzin, propachlor	Water samples analyzed for total-recoverable pesticides. Alachlor (10.1 µg/L), atrazine (47.9 µg/L), metolachlor (4.10 µg/L), metribuzin (5.60 µg/L), and propachlor (7.70 µg/L) were detected.
2	Big Blue River at Beatrice, Nebr.	3,900	USGS[2]	1978-81	Chlorinated hydrocarbon insecticides, organo-phosphate insecticides, chlorophenoxy-acid herbicides.	Water and bed-material samples analyzed for total-recoverable pesticides. Chlordane detected in 1 of 7 bed-material samples (1.0 µg/kg). DDD detected in 3 of 7 bed-material samples (0.1 to 0.2 µg/kg). DDE detected in 3 of 7 bed-material samples (0.2 µg/kg). DDT detected in 4 of 7 bed-material samples (0.1 to 0.6 µg/kg). Diazinon detected in 4 of 7 water samples (0.01 to 0.07 µg/L). Dieldrin detected in 3 of 7 water samples (0.01 µg/L) and 2 of 7 bed-material samples (0.1 to 0.2 µg/kg). Lindane detected in 1 of 7 bed-material samples (0.2 µg/kg). 2,4-D detected in 5 of 7 water samples (0.02 to 0.64 µg/L). 2,4-T detected in 4 of 7 water samples (0.01 to 0.04 µg/L).
3	Big Blue River near Oketo, Kans.	4,630	USGS[2]	1969-73	Chlorinated hydrocarbon insecticides, organo-phosphate insecticides, chlorophenoxy-acid herbicides.	Water samples analyzed for total-recoverable pesticides. Lindane detected in 1 of 11 samples (0.02 µg/L). 2,4-D detected in 9 of 10 samples (0.05 to 0.45 µg/L). 2,4,5-T detected in 6 of 10 samples (0.02 to 0.08 µg/L).
			KDHE[3]	1973-84	Chlorinated hydrocarbon insecticides, chlorophenoxy-acid herbicides (1979-84), alachlor (1978-84), atrazine (1977-84), dacthal (1979-84), metolachlor (1982-84), metribuzin (1979-84), propachlor (1979-84).	Water samples analyzed for total-recoverable pesticides. Alachlor detected in 3 of 8 samples (0.55 to 3.2 µg/L). Atrazine detected in 5 of 9 samples (1.2 to 13 µg/L). Metolachlor detected in 2 of 4 samples (0.67 to 0.85 µg/L). Metribuzin detected in 2 of 7 samples (0.23 and 0.49 µg/L). Propachlor detected in 1 of 7 samples (8.6 µg/L).
4	Little Blue River at Hollenberg, Kans.	2,750	USGS[2]	1973, 1978-82	Chlorinated hydrocarbon insecticides, organophosphate insecticides (1978-82), chlorophenoxy-acid herbicides.	Water and bed-material samples analyzed for total-recoverable pesticides. Chlordane detected in 1 of 11 water samples (0.2 µg/L). DDT detected in 1 of 11 water samples (0.01 µg/L). Dieldrin detected in 2 of 11 water samples (0.01 µg/L) and 1 of 7 bed-material samples (0.01 µg/kg). Parathion detected in 2 of 8 water samples (0.01 and 0.03 µg/L). 2,4-D detected in 9 of 11 water samples (0.01 to 0.31 µg/L). 2,4,5-T detected in 3 of 11 water samples (0.01 to 0.02 µg/L).
			KDHE[3]	1973-78, 1980-83	Chlordane hydrocarbon insecticides, chlorophenoxy-acid herbicides (1980-83), alachlor (1980-83), atrazine (1970, 1980-83), dacthal (1980-83), metolachlor (1982-83), metribuzin (1980-83), propachlor (1980-83).	Water samples analyzed for total-recoverable pesticides. Atrazine detected in 4 of 5 samples (1.3 to 3.8 µg/L).
5	Washington County State Lake, Kans.	10	KDHE[3]	1979	Chlorinated hydrocarbon insecticides, chlorophenoxy-acid herbicides, alachlor, atrazine dacthal, metribuzin, propachlor.	Water samples analyzed for total-recoverable pesticides. No detections.
6	Big Blue River at Blue Rapids, Kans.	8,440	KDHE[3]	1976-81, 1983-86	Chlorinated hydrocarbon insecticides, chlorophenoxy-acid herbicides, alachlor (1978-81, 1983-86), atrazine (1978-81, 1983-86), dacthal (1979-81, 1983-86), metolachlor (1983-86), metribuzin (1979-81, 1983-86), propachlor (1979-81, 1983-86).	Water samples analyzed for total-recoverable pesticides. Alachlor detected in 3 of 8 samples (0.29 to 2.0 µg/L). Atrazine detected in 4 of 8 samples (4.8 to 13.0 µg/L). Metolachlor detected in 2 of 4 samples (0.56 to 1.60 µg/L). Metribuzin detected in 3 of 7 samples (0.12 to 0.30 µg/L).

Appendix A-1. Summary of pesticide data for previously sampled surface-water sites in the Big Blue River Basin, 1969–86—Continued

Map index number (fig. 1)	Site name	Drainage area (square miles)	Data-collection agency	Period of record	Pesticide analyses	Results (concentrations given in micrograms per liter, µg/L, or micrograms per kilogram, µg/kg)
6	Big Blue River at Blue Rapids, Kans. --Continued	8,440	USACE[4]	1984-85	Chlorinated hydrocarbon insecticides, chlorophenoxy-acid herbicides (1985), alpha benzene hexachloride (1985), beta benzene hexachloride (1985), delta benzene hexachloride (1985), benzene hexachloride (1985), alachlor (1985), atrazine (1985), metolachlor (1985), dacthal (1985), metribuzin (1985), propachlor (1985), strobane (1984).	Water samples analyzed for total-recoverable pesticides. Alachlor detected in 3 to 6 samples (0.08 to 2.60 µg/L). Atrazine detected in 6 of 7 samples (1.6 to 10.0 µg/L). Metolachlor detected in 3 of 6 samples (0.38 to 4.70 µg/L). Metribuzin detected in 1 of 6 samples (1.40 µg/L). Propachlor detected in 2 of 6 samples (0.17 to 0.42 µg/L).
7	Black Vermillion River near Tuttle Creek Lake, Kans.	500	USACE[4]	1984-85	Chlorinated hydrocarbon insecticides, alpha benzene hexachloride (1985), beta benzene hexachloride, delta benzene hexachloride (1985), chlorophenoxy-acid herbicides (1985), alachlor, atrazine, metolachlor (1985), propachlor (1985), strobane (1985).	Water samples analyzed for total-recoverable pesticides. Alachlor detected in 4 of 6 samples (0.13 to 8.10 µg/L). Atrazine detected in 6 of 7 samples (1.8 to 23.0 µg/L). Metolachlor detected in 3 of 6 samples (0.71 to 6.00 µg/L). Metribuzin detected in 1 of 6 samples (2.20 µg/L). Propachlor detected in 1 of 6 samples (10.0 µg/L).
8	Fancy Creek near Tuttle Creek Lake, Kans.	200	USACE[4]	1985	Chlorinated hydrocarbon insecticides, alpha benzene hexachloride, beta benzene hexachloride, delta benzene hexachloride, chlorophenoxy-acid herbicides, alachlor, atrazine, dacthal, metolachlor, metribuzin, propachlor, strobane.	Water samples analyzed for total-recoverable pesticides. Alachlor detected in 2 of 6 samples (0.08 to 0.09 µg/L). Atrazine detected in 3 of 6 samples (5.6 to 17.0 µg/L). Metolachlor detected in 3 of 6 samples (0.93 to 1.70 µg/L). Metribuzin detected in 1 of 6 samples (0.15 µg/L). Propachlor detected in 1 of 6 samples (0.19 µg/L).
9	Tuttle Creek Lake, Kans.	9,630	USACE[4]	1985	Chlorinated hydrocarbon insecticides, alpha benzene hexachloride, beta benzene hexachloride, delta benzene hexachloride, chlorophenoxy-acid herbicides, alachlor, atrazine, dacthal, metolachlor, metribuzin, propachlor, strobane.	Water samples analyzed for total-recoverable pesticides. Alachlor detected in 9 of 12 samples (0.09 to 3.10 µg/L). Atrazine detected in 11 of 12 samples (1.8 to 22 µg/L). Metolachlor detected in 8 of 12 samples (0.39 to 3.20 µg/L). Metribuzin detected in 1 of 12 samples (0.33 µg/L). Propachlor detected in 1 of 12 samples (0.25 µg/L).
			USACE[4]	1984	Chlorinated hydrocarbon insecticides, benzene hexachloride, atrazine, strobane.	Water samples analyzed for total-recoverable pesticides. Atrazine detected at 8.7 µg/L.
			KDHE[3]	1976, 1979, 1984	Chlorinated hydrocarbon insecticides, chlorophenoxy-acid herbicides (1979, 1984), alachlor (1979, 1984), atrazine (1978, 1984), dacthal (1979, 1984), metolachlor (1984), metribuzin (1979, 1984), propachlor (1979, 1984), strobane (1984).	Water samples analyzed for total-recoverable pesticides. Alachlor detected in 4 of 6 samples (0.36 to 0.94 µg/L). Atrazine detected in 5 of 6 samples (2.8 to 13.0 µg/L). Metolachlor detected in 3 of 4 samples (0.90 to 1.20 µg/L).
10	Big Blue River downstream from Tuttle Creek Lake, Kans.	9,640	USACE[4]	1984	Chlorinated hydrocarbon insecticides, benzene hexachloride, atrazine, strobane.	Water samples analyzed for total-recoverable pesticides. Atrazine detected at 5.0 µg/L.
			USACE[4]	1985	Chlorinated hydrocarbon insecticides, chlorophenoxy-acid herbicides, alpha benzene hexachloride, beta benzene hexachloride, delta benzene hexachloride, alachlor, atrazine, dacthal, metolachlor, metribuzin, propachlor, strobane.	Water samples analyzed for total-recoverable pesticides. Alachlor detected in 4 of 6 samples (0.15 to 1.60 µg/L). Atrazine detected in 5 of 6 samples (3.6 to 11.5 µg/L). Metolachlor detected in 4 of 6 samples (0.48 to 1.30 µg/L). Propachlor detected in 1 of 6 samples (0.21 µg/L).
10	Big Blue River downstream from Tuttle Creek Lake, Kans.--Continued	9640	KDHE[3]	1976-86	Chlorinated hydrocarbon insecticides, chlorophenoxy-acid herbicides (1979-86), alachlor (1979-86), atrazine (1978-86), dacthal (1979-86), metolachlor (1980-86), metribuzin (1979-86), propachlor (1979-86).	Water samples analyzed for total-recoverable pesticides. Alachlor detected in 8 of 11 samples (0.25 to 2.40 µg/L). Atrazine detected in 11 of 11 samples (1.9 to 14.0 µg/L). Metolachlor detected in 6 of 9 samples (0.30 to 1.60 µg/L). Metribuzin detected in 1 of 10 samples (0.19 µg/L).

[1]Nebraska Department of Environmental Control.
[2]U.S. Geological Survey.
[3]Kansas Department of Health and Environment. Pesticide data collected during July 1985 appears to be erroneous and are not included.
[4]U.S. Army Corps of Engineers.

Appendix A-2. Hydrologic data for surface-water sites sampled during this investigation, April–December 1986

[<, preceding a value indicates the constituent was not detected at that detection level. --, indicates no sample or measurement. Units are in ft³/s, cubic feet per second; °C, degrees Celsius, µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; µg/L, micrograms per liter; %, percent; and mm, millimeters]

Big Blue River at Marysville, Kans.

(Site 11 on plate 1 and in figure 2. Drainage area = 4,777 square miles; latitude-longitude 39°50'31" - 96°39'39")

Date (month-day-year)	Time (24-hour)	Streamflow, instantaneous (ft^3/s)	Specific conductance (µS/cm)	pH (standard units)	Water temperature (°C)	Carbon, organic total (mg/L as C)	Carbon, organic dissolved (mg/L as C)
04-09-86	1200	808	681	8.3	15.0	12	6.3
05-16-86	1530	4,300	305	7.3	18.0	110	7.2
06-04-86	0935	569	722	8.4	24.5	9.0	5.5
06-05-86	1630	1,350	620	8.1	25.0	9.5	5.7
06-11-86	1445	517	557	8.2	25.0	8.3	6.7
06-18-86	1110	1,050	317	7.5	26.0	50	11
06-25-86	1630	350	508	7.8	28.0	6.6	5.8
07-01-86	0900	8,470	189	7.5	23.0	120	9.2
07-01-86	1855	23,400	189	7.5	23.0	92	7.8
07-02-86	1215	16,800	166	6.3	--	72	7.0
07-07-86	1245	34,400	144	6.6	24.5	36	--
07-09-86	1540	6,980	238	7.0	24.5	35	34
07-29-86	1530	1,340	597	8.2	30.5	6.7	5.4
08-12-86	1650	12,500	230	7.8	20.0	39	6.2
09-10-86	0930	1,320	384	8.0	24.0	18	7.0
09-22-86	0920	1,790	335	7.1	23.0	18	7.0
10-29-86	0730	2,970	883	7.7	12.0	18	12
12-15-86	1330	1,020	780	8.2	4.0	5.9	5.6

Appendix A-2. Hydrologic data for surface-water sites sampled during this investigation, April–December 1986—Continued

Big Blue River at Marysville, Kans.--Continued

Date (month-day-year)	Alachlor, total recoverable (µg/L)	Alachlor, dissolved (µg/L)	Aldrin, total recoverable (µg/L)	Aldrin, dissolved (µg/L)	Atrazine, total recoverable (µg/L)	Atrazine, dissolved (µg/L)	Chlordane, total recoverable (µg/L)	Chlordane, dissolved (µg/L)
04-09-86	<0.25	<0.25	<0.025	<0.025	<1.2	<2.5	<0.30	<0.30
05-16-86	.44	.66	<.025	<.025	4.4	<2.5	<.30	<.30
06-04-86	.33	.30	<.025	<.025	5.7	4.4	<.30	<.30
06-05-86	4.5	4.7	<.025	<.025	12	7.6	<.30	<.30
06-11-86	1.1	1.2	<.025	<.025	13	12	<.30	<.30
06-18-86	1.0	1.4	<.025	<.025	10	11	<.30	<.30
06-25-86	.94	--	<.025	--	15	--	<.30	--
07-01-86	.39	.65	<.025	<.025	7.6	9.2	<.30	<.30
07-01-86	.63	.93	<.025	<.025	7.1	8.0	<.30	<.30
07-02-86	<.25	.43	<.025	<.025	4.1	6.8	<.30	<.30
07-07-86	<.25	.45	<.025	<.025	4.2	5.0	<.30	<.30
07-09-86	.35	.35	<.025	<.025	8.7	2.9	<.30	<.30
07-29-86	<.25	<.25	<.025	<.025	3.4	1.8	<.30	<.30
08-12-86	<.25	<.25	<.025	<.025	2.1	<2.5	<.30	<.30
09-10-86	<.25	<.25	<.025	<.025	1.3	<2.5	<.30	<.30
09-22-86	<.25	<.25	<.025	<.025	1.4	<2.5	<.30	<.30
10-29-86	<.25	--	<.025	--	<1.2	--	<.30	<.30
12-15-86	<.25	<.25	<.025	<.025	<1.2	<2.5	<.30	<.30

Big Blue River at Marysville, Kans.--Continued

Date (month-day-year)	Dacthal, total recoverable (µg/L)	Dacthal, dissolved (µg/L)	O,P' DDT, total recoverable (µg/L)	O,P' DDT, dissolved (µg/L)	P,P' DDT, total recoverable (µg/L)	P,P' DDT, dissolved (µg/L)	Dieldrin, total recoverable (µg/L)	Dieldrin, dissolved (µg/L)
04-09-86	<0.05	<0.05	<0.10	<0.10	<0.10	<0.10	<0.05	<0.05
05-16-86	<.05	<.05	<.10	<.10	<.10	<.10	<.05	<.05
06-04-86	<.05	<.05	<.10	<.10	<.10	<.10	<.05	<.05
06-05-86	<.05	<.05	<.10	<.10	<.10	<.10	<.05	<.05
06-11-86	<.05	<.05	<.10	<.10	<.10	<.10	<.05	<.05
06-18-86	<.05	<.05	<.10	<.10	<.10	<.10	<.05	<.05
06-25-86	<.05	--	<.10	--	<.10	--	<.05	--
07-01-86	<.05	<.05	<.10	<.10	<.10	<.10	<.05	<.05
07-01-86	<.05	<.05	<.10	<.10	<.10	<.10	<.05	<.05
07-02-86	<.05	<.05	<.10	<.10	<.10	<.10	<.05	<.05
07-07-86	<.05	<.05	<.10	<.10	<.10	<.10	<.05	<.05
07-09-86	<.05	<.05	<.10	<.10	<.10	<.10	<.05	<.05
07-29-86	<.05	<.05	<.10	<.10	<.10	<.10	<.05	<.05
08-12-86	<.05	<.05	<.10	<.10	<.10	<.10	<.05	<.05
09-10-86	<.05	<.05	<.10	<.10	<.10	<.10	<.05	<.05
09-22-86	<.05	<.05	<.10	<.10	<.10	<.10	<.05	<.05
10-29-86	<.05	--	<.10	--	<.10	--	<.05	--
12-15-86	<.05	<.05	<.10	<.10	<.10	<.10	<.05	<.05

Appendix A-2. Hydrologic data for surface-water sites sampled during this investigation, April–December 1986—Continued

Big Blue River at Marysville, Kans.--Continued

Date (month-day-year)	Metolachlor, total recoverable (µg/L)	Metolachlor, dissolved (µg/L)	PCB, total recoverable (µg/L)	PCB, dissolved (µg/L)	Propachlor, total recoverable (µg/L)	Propachlor, dissolved (µg/L)	Metribuzin, total recoverable (µg/L)	Metribuzin, dissolved (µg/L)
04-09-86	<0.25	<0.25	<0.5	<0.5	<0.25	<0.25	<0.10	<0.10
05-16-86	1.6	1.3	<.5	<.5	<.25	<.25	<.10	<.10
06-04-86	.46	.28	<.5	<.5	<.25	<.25	<.10	<.10
06-05-86	1.2	.91	<.5	<.5	<.25	<.25	.20	.24
06-11-86	.83	.94	<.5	<.5	<.25	<.25	.21	.27
06-18-86	.59	.78	<.5	<.5	<.25	<.25	.15	.22
06-25-86	1.0	--	<.5	--	<.25	--	.12	--
07-01-86	.74	.75	<.5	<.5	<.25	<.25	.29	.58
07-01-86	.49	.55	<.5	<.5	<.25	<.25	.32	.68
07-02-86	.33	.39	<.5	<.5	<.25	<.25	.13	.39
07-07-86	.45	.93	<.5	<.5	<.25	<.25	<.10	.26
07-09-86	.68	.47	<.5	<.5	<.25	<.25	.18	.19
07-29-86	<.25	<.25	<.5	<.5	<.25	<.25	<.10	<.10
08-12-86	<.25	<.25	<.5	<.5	<.25	<.25	<.10	<.10
09-10-86	<.25	<.25	<.5	<.5	<.25	<.25	<.10	<.10
09-22-86	<.25	<.25	<.5	<.5	<.25	<.25	<.10	<.10
10-29-86	<.25	--	<.5	--	<.25	--	<.10	--
12-15-86	<.25	<.25	<.5	<.5	<.25	<.25	<.10	<.10

Big Blue River at Marysville, Kans.--Continued

Date (month-day-year)	Endrin, total recov-erable (µg/L)	Endrin, dissolved (µg/L)	Lindane, total recov-erable (µg/L)	Lindane, dissolved (µg/L)	Meth-oxychlor, total recov-erable (µg/L)	Meth-oxychlor, dissolved (µg/L)	Toxaphene, total recov-erable (µg/L)	Toxaphene, dissolved (µg/L)	Sediment suspended, (mg/L)
04-09-86	<0.10	<0.10	<0.025	<0.025	<0.20	<0.20	<2	<2	189
05-16-86	<.10	<.10	<.025	<.025	<.20	<.20	<2	<2	5,650
06-04-86	<.10	<.10	<.025	<.025	<.20	<.20	<2	<2	91
06-05-86	<.10	<.10	<.025	<.025	<.20	<.20	<2	<2	207
06-11-86	<.10	<.10	<.025	<.025	<.20	<.20	<2	<2	101
06-18-86	<.10	<.10	<.025	<.025	<.20	<.20	<2	<2	1,640
06-25-86	<.10	--	<.025	--	<.20	--	<2	--	83
07-01-86	<.10	<.10	<.025	<.025	<.20	<.20	<2	<2	9,190
07-01-86	<.10	<.10	<.025	<.025	<.20	<.20	<2	<2	5,810
07-02-86	<.10	<.10	<.025	<.025	<.20	<.20	<2	<2	4,260
07-07-86	<.10	<.10	<.025	<.025	<.20	<.20	<2	<2	1,560
07-09-86	<.10	<.10	<.025	<.025	<.20	<.20	<2	<2	2,370
07-29-86	<.10	<.10	<.025	<.025	<.20	<.20	<2	<2	304
08-12-86	<.10	<.10	<.025	<.025	<.20	<.20	<2	<2	3,060
09-10-86	<.10	<.10	<.025	<.025	<.20	<.20	<2	<2	369
09-22-86	<.10	<.10	<.025	<.025	<.20	<.20	<2	<2	922
10-29-86	<.10	--	<.025	--	<.20	--	<2	--	428
12-15-86	<.10	<.10	<.025	<.025	<.20	<.20	<2	<2	33

Appendix A-2. Hydrologic data for surface-water sites sampled during this investigation, April–December 1986—Continued

Big Blue River at Marysville, Kans.--Continued

Date (month-day-year)	Sediment suspended, fall diameter (% finer than 0.002 mm)	Sediment suspended, fall diameter (% finer than 0.004 mm)	Sediment suspended, fall diameter (% finer than 0.016 mm)	Sediment suspended, sieve diameter (% finer than 0.062 mm)	Sediment suspended, fall diameter (% finer than 0.125 mm)	Sediment suspended, fall diameter (% finer than 0.250 mm)	Sediment suspended, fall diameter (% finer than 0.500 mm)	Sediment suspended, fall diameter (% finer than 1.00 mm)
04-09-86	--	--	--	38	38	42	88	100
05-16-86	48	56	78	100	--	--	--	--
06-04-86	--	--	--	100	--	--	--	--
06-05-86	--	--	--	99	--	--	--	--
06-11-86	--	--	--	100	--	--	--	--
06-18-86	84	93	96	100	--	--	--	--
06-25-86	--	--	--	100	--	--	--	--
07-01-86	32	39	57	90	98	100	--	--
07-01-86	--	54	71	96	99	100	--	--
07-02-86	44	52	68	94	99	100	--	--
07-07-86	40	54	65	90	94	98	100	--
07-09-86	47	53	70	98	--	--	--	--
07-29-86	--	--	--	27	--	--	--	--
08-12-86	40	46	61	88	98	99	100	--
09-10-86	86	93	--	100	--	--	--	--
09-22-86	83	91	96	100	--	--	--	--
10-29-86	--	--	--	--	--	--	--	--
12-15-86	--	--	--	--	--	--	--	--

Little Blue River near Barnes, Kans.

(Site 12 on plate 1 and in figure 2. Drainage area = 3,324 square miles; latitude-longitude 39°46'33" - 96°51'29")

Date (month-day-year)	Time (24-hour)	Stream-flow, instan-taneous (ft^3/s)	Specific conduct-ance (µS/cm)	pH (stan-dard units)	Water temper-ature (°C)	Carbon, organic total (mg/L as C)	Alachlor, total recov-erable (µg/L)	Aldrin, total recov-erable (µg/L)	Atrazine, total recov-erable (µg/L)	Chlordane, total recov-erable (µg/L)	Dacthal, total recov-erable (µg/L)
04-09-86	0830	199	675	8.6	13.0	6.6	<0.25	<0.025	<1.2	<0.30	<0.05
05-16-86	1810	1,370	417	7.8	19.0	64	<.25	<.025	<1.2	<.30	<.05
06-03-86	1515	450	680	8.3	26.5	10	<.25	<.025	6.5	<.30	<.05
06-11-86	1230	429	596	8.3	23.0	8.7	<.25	<.025	9.8	<.30	<.05
06-18-86	1340	370	644	7.6	30.0	6.5	.35	<.025	9.8	<.30	<.05
06-25-86	1415	399	450	7.8	29.0	31	.39	<.025	5.0	<.30	<.05
06-30-86	1520	1,290	335	8.1	28.5	82	.42	<.025	6.4	<.30	<.05
07-01-86	1420	1,940	348	7.6	26.0	21	1.6	<.025	17	<.30	<.05
07-07-86	1515	3,870	232	7.6	--	43	1.5	<.025	9.6	<.30	<.05
07-30-86	1030	304	649	8.3	28.0	6.2	<.25	<.025	1.9	<.30	<.05
08-13-86	0850	2,530	190	7.6	20.5	37	<.25	<.025	1.5	<.30	<.05
09-10-86	1505	1,890	213	8.0	25.5	42	<.25	<.025	<1.2	<.30	<.05
09-22-86	1245	485	407	7.6	24.5	25	<.25	<.025	<1.2	<.30	<.05
10-29-86	1500	749	576	8.1	14.0	7.9	<.25	<.025	<1.2	<.30	<.05
12-15-86	1205	473	785	8.3	3.5	4.8	<.25	<.025	<1.2	<.30	<.05

Appendix A-2. Hydrologic data for surface-water sites sampled during this investigation, April–December 1986—Continued

Little Blue River near Barnes, Kans.--Continued

Date (month-day-year)	O,P' DDT, total recov-erable (µg/L)	P,P' DDT, total recov-erable (µg/L)	Dieldrin, total recov-erable (µg/L)	Meto-lachlor, total recov-erable (µg/L)	PCB, total recov-erable (µg/L)	Propa-chlor, total recov-erable (µg/L)	Metri-buzin, total recov-erable (µg/L)	Endrin, total recov-erable (µg/L)	Lindane, total recov-erable (µg/L)	Meth-oxychlor, total recov-erable (µg/L)
04-09-86	<0.10	<0.10	<0.05	<0.25	<0.50	<0.25	<0.10	<0.10	<0.025	<0.20
05-16-86	<.10	<.10	<.05	<.25	<.50	<.25	<.10	<.10	<.025	<.20
06-03-86	<.10	<.10	<.05	.51	<.50	<.25	.13	<.10	<.025	<.20
06-11-86	<.10	<.10	<.05	.73	<.50	<.25	<.10	<.10	<.025	<.20
06-18-86	<.10	<.10	<.05	.87	<.50	<.25	<.10	<.10	<.025	<.20
06-25-86	<.10	<.10	<.05	.44	<.50	<.25	.14	<.10	<.025	<.20
06-30-86	<.10	<.10	<.05	.83	<.50	<.25	.14	<.10	<.025	<.20
07-01-86	<.10	<.10	<.05	6.3	<.50	<.25	.99	<.10	<.025	<.20
07-07-86	<.10	<.10	<.05	1.7	<.50	<.25	.43	<.10	<.025	<.20
07-30-86	<.10	<.10	<.05	<.25	<.50	<.25	<.10	<.10	<.025	<.20
08-13-86	<.10	<.10	<.05	<.25	<.50	<.25	<.10	<.10	<.025	<.20
09-10-86	<.10	<.10	<.05	<.25	<.50	<.25	<.10	<.10	<.025	<.20
09-22-86	<.10	<.10	<.05	<.25	<.50	<.25	<.10	<.10	<.025	<.20
10-29-86	<.10	<.10	<.05	<.25	<.50	<.25	<.10	<.10	<.025	<.20
12-15-86	<.10	<.10	<.05	<.25	<.50	<.25	<.10	<.10	<.025	<.20

Little Blue River near Barnes, Kans.--Continued

Date (month-day-year)	Toxa-phene, total recov-erable (µg/L)	Sediment, sus-pended (mg/L)	Sediment, sus-pended fall diameter (% finer than 0.002 mm)	Sediment, sus-pended fall diameter (% finer than 0.004 mm)	Sediment, sus-pended fall diameter (% finer than 0.016 mm)	Sediment, sus-pended sieve diameter (% finer than 0.062 mm)	Sediment, sus-pended fall diameter (% finer than 0.125 mm)	Sediment, sus-pended fall diameter (% finer than 0.250 mm)	Sediment, sus-pended fall diameter (% finer than 0.500 mm)	Sediment, sus-pended fall diameter (% finer than 1.00 mm)
04-09-86	<2	71	--	--	--	83	88	100	--	--
05-16-86	<2	3,860	38	42	60	93	99	99	100	--
06-03-86	<2	345	--	--	--	66	66	68	84	89
06-11-86	<2	230	--	--	--	95	--	--	--	--
06-18-86	<2	246	--	--	--	93	--	--	--	--
06-25-86	<2	954	74	83	91	99	--	--	--	--
06-30-86	<2	3,520	41	49	68	95	100	--	--	--
07-01-86	<2	3,460	50	57	75	99	100	--	--	--
07-07-86	<2	2,520	46	49	62	94	97	100	--	--
07-30-86	<2	114	--	--	--	99	--	--	--	--
08-13-86	<2	2,670	44	50	66	93	99	100	--	--
09-10-86	<2	2,130	57	64	78	98	--	--	--	--
09-22-86	<2	1,140	74	84	90	98	--	--	--	--
10-29-86	<2	--	--	--	--	--	--	--	--	--
12-15-86	<2	--	--	--	--	--	--	--	--	--

Appendix A-2. Hydrologic data for surface-water sites sampled during this investigation, April–December 1986—Continued

Black Vermillion River near Frankfort, Kans.

(Site 13 on plate 1 and in figure 2. Drainage area = 410 square miles; latitude-longitude 39°41'03" - 96°26'15")

Date (month-day-year)	Time (24-hour)	Streamflow, instantaneous (ft^3/s)	Specific conductance (µS/cm)	pH (standard units)	Water temperature (°C)	Carbon, organic total (mg/L as C)	Alachlor, total recoverable (µg/L)	Aldrin, total recoverable (µg/L)	Atrazine, total recoverable (µg/L)	Chlordane, total recoverable (µg/L)	Dacthal, total recoverable (µg/L)
04-09-86	1530	205	632	8.0	15.0	10	<0.25	<0.025	<1.2	<0.3	<0.05
05-16-86	1235	5,250	130	--	17.5	110	<.25	<.025	1.4	<.3	<.05
05-17-86	0920	7,660	125	7.8	15.0	78	<.25	<.025	1.7	<.3	<.05
06-04-86	1455	100	677	8.1	24.0	6.0	<.25	<.025	2.7	<.3	<.05
06-05-86	1345	320	411	7.5	22.5	49	.38	<.025	16	<.3	<.05
06-11-86	1645	103	502	8.1	24.0	7.5	.73	<.025	7.5	<.3	<.05
06-17-86	1345	65	683	8.7	27.0	6.6	<.25	<.025	1.8	<.3	<.05
06-26-86	1100	49	625	7.8	26.5	5.1	<.25	<.025	2.3	<.3	<.05
06-30-86	1430	1,160	270	7.7	23.0	75	2.7	<.025	22	<.3	<.05
07-02-86	1320	1,270	--	--	--	--	3.4	<.025	21	<.3	<.05
07-02-86	1535	899	--	--	--	--	3.0	<.025	19	<.3	<.05
07-07-86	1255	1,370	256	7.8	26.0	35	.42	<.025	5.0	<.3	<.05
07-29-86	1200	30	528	8.4	28.0	10	<.25	<.025	3.4	<.3	<.05
08-12-86	1210	330	140	8.0	18.5	52	<.25	<.025	<1.2	<.3	<.05
09-09-86	1140	6.0	616	7.5	18.5	4.6	<.25	<.025	<1.2	<.3	<.05
09-22-86	1040	55	594	8.3	27.0	9.4	<.25	<.025	1.8	<.3	<.05
10-29-86	1200	116	609	8.1	12.0	7.4	<.25	<.025	1.2	<.3	<.05
12-15-86	0945	158	690	9.0	3.0	4.3	<.25	<.025	<1.2	<.3	<.05

Black Vermillion River near Frankfort, Kans.--Continued

Date (month-day-year)	O,P' DDT, total recoverable (µg/L)	P,P' DDT, total recoverable (µg/L)	Dieldrin, total recoverable (µg/L)	Metolachlor, total recoverable (µg/L)	PCB, total recoverable (µg/L)	Propachlor, total recoverable (µg/L)	Metribuzin, total recoverable (µg/L)	Endrin, total recoverable (µg/L)	Lindane, total recoverable (µg/L)	Methoxychlor, total recoverable (µg/L)	Toxaphene, total recoverable (µg/L)
04-09-86	<0.10	<0.10	<0.05	<0.25	<0.5	<0.25	<0.10	<0.10	<0.025	<0.20	<2
05-16-86	<.10	<.10	<.05	.44	<.5	<.25	.13	<.10	<.025	<.20	<2
05-17-86	<.10	<.10	<.05	.32	<.5	<.25	<.10	<.10	<.025	<.20	<2
06-04-86	<.10	<.10	<.05	.65	<.5	<.25	<.10	<.10	<.025	<.20	<2
06-05-86	<.10	<.10	<.05	.80	<.5	9.9	1.10	<.10	<.025	<.20	<2
06-11-86	<.10	<.10	<.05	1.5	<.5	.58	.35	<.10	<.025	<.20	<2
06-17-86	<.10	<.10	<.05	.35	<.5	<.25	<.10	<.10	<.025	<.20	<2
06-26-86	<.10	<.10	<.05	.40	<.5	<.25	<.10	<.10	<.025	<.20	<2
06-30-86	<.10	<.10	<.05	2.9	<.5	2.7	.89	<.10	<.025	<.20	<2
07-02-86	<.10	<.10	<.05	7.3	<.5	.71	1.70	<.10	<.025	<.20	<2
07-02-86	<.10	<.10	<.05	6.5	<.5	.62	1.40	<.10	<.025	<.20	<2
07-07-86	<.10	<.10	<.05	1.3	<.5	<.25	.32	<.10	<.025	<.20	<2
07-29-86	<.10	<.10	<.05	.55	<.5	<.25	<.10	<.10	<.025	<.20	<2
08-12-86	<.10	<.10	<.05	<.25	<.5	<.25	<.10	<.10	<.025	<.20	<2
09-09-86	<.10	<.10	<.05	<.25	<.5	<.25	<.10	<.10	<.025	<.20	<2
09-22-86	<.10	<.10	<.05	<.25	<.5	<.25	<.10	<.10	<.025	<.20	<2
10-29-86	<.10	<.10	<.05	<.25	<.5	<.25	<.10	<.10	<.025	<.20	<2
12-15-86	<.10	<.10	<.05	<.25	<.5	<.25	<.10	<.10	<.025	<.20	<2

Appendix A-2. Hydrologic data for surface-water sites sampled during this investigation, April–December 1986—Continued

Black Vermillion River near Frankfort, Kans.--Continued

Date (month-day-year)	Sediment, suspended (mg/L)	Sediment, suspended fall diameter (% finer than 0.002 mm)	Sediment, suspended fall diameter (% finer than 0.004 mm)	Sediment, suspended fall diameter (% finer than 0.016 mm)	Sediment, suspended sieve diameter (% finer than 0.062 mm)	Sediment, suspended fall diameter (% finer than 0.125 mm)	Sediment, suspended fall diameter (% finer than 0.250 mm)	Sediment, suspended fall diameter (% finer than 0.500 mm)	Sediment, suspended fall diameter (% finer than 1.00 mm)	Sediment, suspended fall diameter (% finer than 2.00 mm)
04-09-86	385	40	45	64	95	--	--	--	--	--
05-16-86	7,370	48	54	72	98	100	--	--	--	--
05-17-86	2,870	66	84	94	100	--	--	--	--	--
06-04-86	184	--	--	--	99	--	--	--	--	--
06-05-86	2,810	44	49	66	81	81	83	87	95	100
06-11-86	181	--	--	--	99	--	--	--	--	--
06-17-86	105	--	--	--	96	--	--	--	--	--
06-26-86	102	--	--	--	96	--	--	--	--	--
06-30-86	3,980	46	56	72	99	100	--	--	--	--
07-02-86	2,540	56	61	80	99	--	--	--	--	--
07-02-86	1,910	37	51	76	99	--	--	--	--	--
07-07-86	1,520	24	40	69	100	--	--	--	--	--
07-29-86	27	--	--	--	95	--	--	--	--	--
08-12-86	5,260	40	46	67	98	--	--	--	--	
09-09-86	51	--	--	--	86	--	--	--	--	--
09-22-86	264	--	--	--	72	--	--	--	--	--
10-29-86	--	--	--	--	--	--	--	--	--	--
12-15-86	--	--	--	--	--	--	--	--	--	--

Fancy Creek at Winkler, Kans.

(Site 14 on plate 1 and in figure 2. Drainage area = 174 square miles; latitude-longitude 39°28'20" - 96°49'55")

Date (month-day-year)	Time (24-hour)	Streamflow, instantaneous (ft^3/s)	Specific conductance (µS/cm)	pH (standard units)	Water temperature (°C)	Carbon, organic total (mg/L as C)	Alachlor, total recoverable (µg/L)	Aldrin, total recoverable (µg/L)	Atrazine, total recoverable (µg/L)	Chlordane, total recoverable (µg/L)
04-08-86	1715	4.5	403	8.1	15.0	17	<0.25	<0.025	<1.2	<0.30
05-16-86	2015	10,400	138	8.0	17.5	110	<.25	<.025	3.9	<.30
05-17-86	1130	1,110	264	7.5	14.5	71	<.25	<.025	2.7	<.30
06-03-86	1300	4.5	905	8.2	23.5	4.3	<.25	<.025	<1.2	<.30
06-05-86	1500	74	448	7.5	22.5	30	2.2	<.025	51	<.30
06-11-86	1100	7.7	797	8.1	23.5	5.4	<.25	<.025	4.4	<.30
06-18-86	1525	40	734	7.7	28.0	6.5	1.7	<.025	25	<.30
06-25-86	1215	2.0	751	7.8	26.5	4.9	.63	<.025	8.6	<.30
06-30-86	1340	6,100	167	8.2	22.0	94	.47	<.025	10	<.30
07-02-86	1610	23	416	8.0	28.0	28	<.25	<.025	4.6	<.30
07-30-86	1210	43	783	8.2	29.0	8.8	<.25	<.025	<1.2	<.30
08-13-86	1115	75	405	7.8	21.5	15	<.25	<.025	1.8	<.30
09-11-86	1615	7.0	670	8.1	22.0	8.2	<.25	<.025	<1.2	<.30
09-22-86	1505	4.5	813	8.1	25.0	6.0	<.25	<.025	<1.2	<.30
10-30-86	0800	12	876	8.2	11.5	4.8	<.25	<.025	<1.2	<.30
12-16-86	0840	7.7	98	8.8	3.5	2.8	<.25	<.025	<1.2	<.30

Appendix A-2. Hydrologic data for surface-water sites sampled during this investigation, April–December 1986—Continued

Fancy Creek at Winkler, Kans.--Continued

Date (month-day-year)	Dacthal, total recov-erable (µg/L)	O,P' DDT, total recov-erable (µg/L)	P,P' DDT, total recov-erable (µg/L)	Dieldrin, total recov-erable (µg/L)	Meto-lachlor, total recov-erable (µg/L)	PCB, total recov-erable (µg/L)	Propa-chlor, total recov-erable (µg/L)	Metri-buzin, total recov-erable (µg/L)	Endrin, total recov-erable (µg/L)	Lindane, total recov-erable (µg/L)
04-08-86	<0.05	<0.10	<0.10	<0.05	<0.25	<0.5	<0.25	<0.10	<0.10	<0.025
05-16-86	<.05	<.10	<.10	<.05	.60	<.5	<.25	<.10	<.10	<.025
05-17-86	<.05	<.10	<.10	<.05	.41	<.5	<.25	<.10	<.10	<.025
06-03-86	<.05	<.10	<.10	<.05	.31	<.5	<.25	<.10	<.10	<.025
06-05-86	<.05	<.10	<.10	<.05	22	<.5	1.0	.52	<.10	<.025
06-11-86	<.05	<.10	<.10	<.05	.53	<.5	<.25	<.10	<.10	<.025
06-18-86	<.05	<.10	<.10	<.05	5.4	<.5	1.9	.43	<.10	<.025
06-25-86	<.05	<.10	<.10	<.05	2.9	<.5	<.25	.56	<.10	<.025
06-30-86	<.05	<.10	<.10	<.05	1.5	<.5	<.25	.27	<.10	<.025
07-02-86	<.05	<.10	<.10	<.05	.84	<.5	<.25	.18	<.10	<.025
07-30-86	<.05	<.10	<.10	<.05	<.25	<.5	<.25	<.10	<.10	<.025
08-13-86	<.05	<.10	<.10	<.05	<.25	<.5	<.25	<.10	<.10	<.025
09-11-86	<.05	<.10	<.10	<.05	<.25	<.5	<.25	<.10	<.10	<.025
09-22-86	<.05	<.10	<.10	<.05	<.25	<.5	<.25	<.10	<.10	<.025
10-30-86	<.05	<.10	<.10	<.05	<.25	<.5	<.25	<.10	<.10	<.025
12-16-86	<.05	<.10	<.10	<.05	<.25	<.5	<.25	<.10	<.10	<.025

Fancy Creek at Winkler, Kans.--Continued

Date (month-day-year)	Meth-oxychlor, total recov-erable (µg/L)	Toxa-phene, total recov-erable (µg/L)	Sediment, suspended (mg/L)	Sediment, suspended fall diameter (% finer than 0.002 mm)	Sediment, suspended fall diameter (% finer than 0.004 mm)	Sediment, suspended fall diameter (% finer than 0.016 mm)	Sediment, suspended sieve diameter (% finer than 0.062 mm)	Sediment, suspended fall diameter (% finer than 0.125 mm)	Sediment, suspended fall diameter (% finer than 0.250 mm)
04-08-86	0.20	<2	274	--	--	99	99	--	--
05-16-86	<.20	<2	6,650	48	54	71	99	100	--
05-17-86	<.20	<2	4,900	42	47	63	100	--	--
06-03-86	<.20	<2	66	--	--	--	92	--	--
06-05-86	<.20	<2	1,030	70	81	94	100	--	--
06-11-86	<.20	<2	71	--	--	--	80	--	--
06-18-86	<.20	<2	65	--	--	--	94	--	--
06-25-86	<.20	<2	42	--	--	--	99	--	--
06-30-86	<.20	<2	6,020	45	54	70	96	99	100
07-02-86	<.20	<2	1,010	68	71	87	100	--	--
07-30-86	<.20	<2	51	--	--	--	59	--	--
08-13-86	<.20	<2	305	--	--	--	99	--	--
09-11-86	<.20	<2	112	--	--	--	99	--	--
09-22-86	<.20	<2	33	--	--	--	91	--	--
10-30-86	<.20	<2	--	--	--	--	--	--	--
12-16-86	<.20	<2	--	--	--	--	--	--	--

Appendix A-2. Hydrologic data for surface-water sites sampled during this investigation, April–December 1986—Continued

Tuttle Creek Lake

(Sites 15-19 on plate 1 and in figure 2. Drainage area = 9,630 square miles)

Site number (fig. 2)	Latitude-longitude	Date (month-day-year)	Time (24-hour)	Depth at sample location, total (feet)	Sampling depth (feet)	Specific conductance (µS/cm)	pH (standard units)	Water temperature (°C)	Transparency, secchi disk (inches)	Oxygen, dissolved (mg/L)
15	39°27'06"	04-07-86	1520	5.9	1.0	448	7.8	17.5	--	7.9
	96°42'55"	05-05-86	1225	9.8	1.0	356	7.7	19.0	5.90	7.6
		06-02-86	1210	1.6	1.0	638	7.9	24.0	7.90	8.7
		08-05-86	1145	2.5	1.0	632	7.8	22.0	7.90	7.1
		09-02-86	1200	2.0	1.0	642	7.7	23.0	5.90	7.3
		10-01-86	1220	11	1.0	213	7.2	19.0	3.94	6.1
		10-28-86	1200	66	1.0	556	8.0	12.0	11.8	9.8
16	39°22'50"	04-07-86	1425	26	1.0	545	8.2	17.0	--	8.8
	96°41'42"	05-06-86	1200	39	1.0	471	8.2	18.0	23.6	7.7
		06-02-86	1145	34	1.0	476	8.1	24.5	19.7	9.8
		07-08-86	1150	46	1.0	300	7.7	26.5	3.90	5.3
		08-05-86	1115	35	1.0	--	7.9	--	9.80	--
		08-05-86	1120	35	30	--	--	--	9.80	--
		09-02-86	1110	32	1.0	347	7.8	23.0	9.80	6.4
		10-01-86	1155	42	1.0	412	7.6	21.5	11.8	8.2
		10-28-86	1135	38	1.0	436	7.8	13.5	--	8.2
17	39°19'02"	04-07-86	1340	39	1.0	602	8.6	16.5	--	11.8
	96°38'59"	05-06-86	1120	52	1.0	452	8.2	18.0	19.7	7.8
		06-02-86	1115	52	1.0	377	8.1	22.0	31.5	7.9
		06-02-86	1120	52	40	600	6.8	18.0	31.5	1.7
		07-08-86	1115	66	1.0	347	7.8	26.5	5.9	5.6
		08-05-86	1050	43	1.0	320	8.0	24.5	7.8	6.5
		09-02-86	1045	48	1.0	339	7.9	23.0	11.8	6.5
		10-01-86	1130	62	1.0	402	7.6	22.0	15.8	8.0
		10-28-86	1105	55	1.0	292	7.8	13.5	--	8.0
18	39°18'03"	04-07-86	1315	22	1.0	600	8.6	17.0	--	11.8
	96°40'08"	05-06-86	1100	31	1.0	507	8.4	18.0	15.7	7.8
		06-02-86	1030	25	1.0	375	8.2	22.0	2.36	9.3
		07-08-86	1050	36	1.0	398	7.5	26.5	11.8	6.6
		08-05-86	1030	21	1.0	328	7.9	24.0	7.9	6.2
		09-02-86	1030	20	1.0	341	7.7	23.0	11.8	7.4
		10-01-86	1110	27	1.0	390	7.7	22.0	15.8	7.8
		10-01-86	1115	27	25	384	8.0	22.0	15.8	7.1
		10-28-86	1045	25	1.0	290	7.3	13.5	--	7.7
19	39°15'39"	04-07-86	1230	66	1.0	588	8.7	16.0	78.8	14.1
	96°35'53"	05-06-86	1020	65	1.0	552	8.4	18.0	78.7	8.4
		05-06-86	1030	65	50	573	8.7	16.0	78.8	7.5
		06-02-86	1010	46	1.0	375	7.8	20.0	27.6	6.5
		07-08-86	1015	66	1.0	415	7.4	26.0	13.8	5.0
		08-05-86	1000	46	1.0	315	7.5	24.0	9.8	8.1
		09-02-86	1000	45	1.0	343	7.5	23.0	11.8	6.3
		09-02-86	1005	45	45	336	7.7	23.0	11.8	4.4
		10-01-86	1040	56	1.0	362	7.7	22.0	15.8	8.5
		10-28-86	1000	50	50	309	7.3	13.0	--	5.0
		10-28-86	1005	50	1.0	304	8.0	14.5	--	7.7

Appendix A-2. Hydrologic data for surface-water sites sampled during this investigation, April–December 1986—Continued

Tuttle Creek Lake--Continued

Site number (fig. 2)	Date (month-day-year)	Solids, residue at 105 °C, suspended (mg/L)	Carbon, organic total (mg/L)	Alachlor, total recov-erable (µg/L)	Aldrin, total recov-erable (µg/L)	Atrazine, total recov-erable (µg/L)	Chlordane, total recov-erable (µg/L)	Dacthal, total recov-erable (µg/L)	O,P' DDT, total recov-erable (µg/L)	P,P' DDT, total recov-erable (µg/L)
15	04-07-86	101	14	<0.25	<0.025	<1.2	<0.30	<0.05	<0.10	<0.10
	05-06-86	110	14	.94	<.025	5.5	<.30	<.05	<.10	<.10
	06-02-86	181	9.8	.43	<.025	3.7	<.30	<.05	<.10	<.10
	08-05-86	97	6.5	<.25	<.025	2.4	<.30	<.05	<.10	<.10
	09-02-86	437	11	<.25	<.025	2.1	<.30	<.05	<.10	<.10
	10-01-86	362	18	<.25	<.025	<1.2	<.30	<.05	<.10	<.10
	10-28-86	105	7.4	<.25	<.025	<1.2	<.30	<.05	<.10	<.10
16	04-07-86	29	11	<.25	<.025	<1.2	<.30	<.05	<.10	<.10
	05-06-86	7	7.4	.52	<.025	3.7	<.30	<.05	<.10	<.10
	06-02-86	21	6.2	.64	<.025	5.6	<.30	<.05	<.10	<.10
	07-08-86	146	11	.79	<.025	10	<.30	<.05	<.10	<.10
	08-05-86	20	7.1	.25	<.025	6.3	<.30	<.05	<.10	<.10
	08-05-86	20	5.2	--	--	--	--	--	--	--
	09-02-86	24	6.1	<.25	<.025	4.1	<.30	<.05	<.10	<.10
	10-01-86	26	5.7	<.25	<.025	2.0	<.30	<.05	<.10	<.10
	10-28-86	26	6.9	<.25	<.025	<1.2	<.30	<.05	<.10	<.10
17	04-07-86	18	10	<.25	<.025	<1.2	<.30	<.05	<.10	<.10
	05-06-86	7	7.9	.57	<.025	4.0	<.30	<.05	<.10	<.10
	06-02-86	5	5.6	.58	<.025	5.2	<.30	<.05	<.10	<.10
	06-02-86	--	7.8	.49	<.025	4.7	<.30	<.05	<.10	<.10
	07-08-86	32	7.1	.93	<.025	11	<.30	<.05	<.10	<.10
	08-05-86	9	6.2	.51	<.025	8.7	<.30	<.05	<.10	<.10
	09-02-86	13	5.6	<.25	<.025	4.7	<.30	<.05	<.10	<.10
	10-01-86	16	5.0	<.25	<.025	3.1	<.30	<.05	<.10	<.10
	10-28-86	67	7.7	<.25	<.025	1.5	<.30	<.05	<.10	<.10
18	04-07-86	18	9.0	<.25	<.025	<1.2	<.30	<.05	<.10	<.10
	05-06-86	11	7.1	.38	<.025	3.3	<.30	<.05	<.10	<.10
	06-02-86	8	6.0	.60	<.025	5.6	<.30	<.05	<.10	<.10
	07-08-86	8	5.1	.86	<.025	9.5	<.30	<.05	<.10	<.10
	08-05-86	27	5.7	.44	<.025	8.4	<.30	<.05	<.10	<.10
	09-02-86	10	5.7	<.25	<.025	5.4	<.30	<.05	<.10	<.10
	10-01-86	12	4.8	<.25	<.025	3.7	<.30	<.05	<.10	<.10
	10-01-86	--	5.3	--	--	--	--	--	--	--
	10-28-86	85	8.8	<.25	<.025	1.7	<.30	<.05	<.10	<.10
19	04-07-86	20	8.8	<.25	<.025	<1.2	<.30	<.05	<.10	<.10
	05-06-86	3	6.4	<.25	<.025	2.5	<.30	<.05	<.10	<.10
	05-06-86	15	6.2	<.25	<.025	2.8	<.30	<.05	<.10	<.10
	06-02-86	6	6.0	.67	<.025	5.9	<.30	<.05	<.10	<.10
	07-08-86	6	5.3	.88	<.025	9.2	<.30	<.05	<.10	<.10
	08-05-86	19	5.4	.46	<.025	8.5	<.30	<.05	<.10	<.10
	09-02-86	13	5.6	<.25	<.025	5.6	<.30	<.05	<.10	<.10
	09-02-86	--	8.3	--	<.--	--	--	--	--	--
	10-01-86	18	4.8	<.25	<.025	4.2	<.30	<.05	<.10	<.10
	10-28-86	48	8.5	<.25	<.025	<1.2	<.30	<.05	<.10	<.10
	10-28-86	--	7.0	<.25	<.025	1.8	<.30	<.05	<.10	<.10

Appendix A-2. Hydrologic data for surface-water sites sampled during this investigation, April–December 1986—Continued

Tuttle Creek Lake--Continued

Site number (fig. 2)	Date (month-day-year)	Dieldrin, total recoverable (µg/L)	Metolachlor, total recoverable (µg/L)	PCB, total recoverable (µg/L)	Propachlor, total recoverable (µg/L)	Metribuzin, total recoverable (µg/L)	Endrin, total recoverable (µg/L)	Lindane, total recoverable (µg/L)	Methoxychlor, total recoverable (µg/L)	Toxaphene, total recoverable (µg/L)
15	04-07-86	<0.05	<0.25	<0.5	<0.25	<0.10	<0.10	<0.025	<0.20	<2
	05-06-86	<.05	.75	<.5	<.25	<.10	<.10	<.025	<.20	<2
	06-02-86	<.05	.62	<.5	<.25	<.10	<.10	<.025	<.20	<2
	08-05-86	<.05	<.25	<.5	<.25	<.10	<.10	<.025	<.20	<2
	09-02-86	<.05	<.25	<.5	<.25	<.10	<.10	<.025	<.20	<2
	10-01-86	<.05	<.25	<.5	<.25	<.10	<.10	<.025	<.20	<2
	10-28-86	<.05	<.25	<.5	<.25	<.10	<.10	<.025	<.20	<2
16	04-07-86	<.05	<.25	<.5	<.25	<.10	<.10	<.025	<.20	<2
	05-06-86	<.05	.58	<.5	<.25	<.10	<.10	<.025	<.20	<2
	06-02-86	<.05	.86	<.5	<.25	<.10	<.10	<.025	<.20	<2
	07-08-86	<.05	1.0	<.5	<.25	<.23	<.10	<.025	<.20	<2
	08-05-86	<.05	.66	<.5	<.25	<.10	<.10	<.025	<.20	<2
	08-05-86	--	--	--	--	--	--	--	--	--
	09-02-86	<.05	.36	<.5	<.25	<.10	<.10	<.025	<.20	<2
	10-01-86	<.05	<.25	<.5	<.25	<.10	<.10	<.025	<.20	<2
	10-28-86	<.05	<.25	<.5	<.25	<.10	<.10	<.025	<.20	<2
17	04-07-86	<.05	<.25	<.5	<.25	<.10	<.10	<.025	<.20	<2
	05-06-86	<.05	.60	<.5	<.25	<.10	<.10	<.025	<.20	<2
	06-02-86	<.05	.91	<.5	<.25	<.10	<.10	<.025	<.20	<2
	06-02-86	<.05	.81	<.5	<.25	<.10	<.10	<.025	<.20	<2
	07-08-86	<.05	1.2	<.5	<.25	.24	<.10	<.025	<.20	<2
	08-05-86	<.05	.96	<.5	<.25	.15	<.10	<.025	<.20	<2
	09-02-86	<.05	.43	<.5	<.25	<.10	<.10	<.025	<.20	<2
	10-01-86	<.05	.29	<.5	<.25	<.10	<.10	<.025	<.20	<2
	10-28-86	<.05	<.25	<.5	<.25	<.10	<.10	<.025	<.20	<2
18	04-07-86	<.05	<.25	<.5	<.25	<.10	<.10	<.025	<.20	<2
	05-06-86	<.05	.47	<.5	<.25	<.10	<.10	<.025	<.20	<2
	06-02-86	<.05	1.0	<.5	<.25	<.10	<.10	<.025	<.20	<2
	07-08-86	<.05	1.1	<.5	<.25	.22	<.10	<.025	<.20	<2
	08-05-86	<.05	.91	<.5	<.25	.13	<.10	<.025	<.20	<2
	09-02-86	<.05	.52	<.5	<.25	<.10	<.10	<.025	<.20	<2
	10-01-86	<.05	.33	<.5	<.25	<.10	<.10	<.025	<.20	<2
	10-01-86	--	--	--	--	--	--	--	--	--
	10-28-86	<.05	<.25	<.5	<.25	<.10	<.10	<.025	<.20	<2
19	04-07-86	<.05	<.25	<.5	<.25	<.10	<.10	<.025	<.20	<2
	05-06-86	<.05	<.25	<.5	<.25	<.10	<.10	<.025	<.20	<2
	05-06-86	<.05	<.25	<.5	<.25	<.10	<.10	<.025	<.20	<2
	06-02-86	<.05	1.0	<.5	<.25	<.10	<.10	<.025	<.20	<2
	07-08-86	<.05	1.1	<.5	<.25	.21	<.10	<.025	<.20	<2
	08-05-86	<.05	.91	<.5	<.25	.15	<.10	<.025	<.20	<2
	09-02-86	<.05	.53	<.5	<.25	<.10	<.10	<.025	<.20	<2
	09-02-86	--	--	--	--	--	--	--	--	--
	10-01-86	<.05	.41	<.5	<.25	<.10	<.10	<.025	<.20	<2
	10-28-86	<.05	<.25	<.5	<.25	<.10	<.10	<.025	<.20	<2
	10-28-86	<.05	<.25	<.5	<.25	<.10	<.10	<.025	<.20	<2

Appendix A-2. Hydrologic data for surface-water sites sampled during this investigation, April–December 1986—Continued

Big Blue River near Manhattan, Kans.

(Site 20 on plate 1 and in figure 2. Drainage area = 9,640 square miles; latitude-longitude 39°14'14" - 96°34'16")

Date (month-day-year)	Time (24-hour)	Streamflow, instantaneous (ft^3/s)	Specific conductance (µS/cm)	pH (standard units)	Water temperature (°C)	Carbon, organic total (mg/L as C)	Alachlor, total recoverable (µg/L)	Aldrin, total recoverable (µg/L)
04-08-86	1400	2,330	617	8.2	13.5	9.5	<0.25	<0.025
05-07-86	0920	7,040	--	--	--	--	<.25	<.025
06-02-86	1430	2,370	392	8.0	20.5	7.1	.60	<.025
06-18-86	1710	36	421	8.3	29.0	7.5	<.25	<.025
07-08-86	1250	23,300	--	--	--	15	.61	<.025
07-30-86	1445	1,360	298	7.9	28.0	6.0	.49	<.025
08-13-86	1515	10,600	331	8.0	26.5	6.5	.35	<.025
09-11-86	1040	3,160	349	8.3	22.5	5.7	<.25	<.025
09-22-86	1715	2,620	352	7.8	22.5	5.8	<.25	<.025
10-28-86	1400	8,120	291	8.0	--	10	<.25	<.025
12-16-86	1030	5,420	670	7.2	4.5	5.2	<.25	<.025

Big Blue River near Manhattan, Kans.--Continued

Date (month-day-year)	Atrazine, total recoverable (µg/L)	Chlordane, total recoverable (µg/L)	Dacthal, total recoverable (µg/L)	O,P' DDT, total recoverable (µg/L)	P,P' DDT, total recoverable (µg/L)	Dieldrin, total recoverable (µg/L)	Metolachlor, total recoverable (µg/L)	PCB, total recoverable (µg/L)	Propachlor, total recoverable (µg/L)
04-08-86	1.6	<0.30	<0.05	<0.10	<0.10	<0.05	<0.25	<0.5	<0.25
05-07-86	2.2	<.30	<.05	<.10	<.10	<.05	<.25	<.5	<.25
06-02-86	5.0	<.30	<.05	<.10	<.10	<.05	.86	<.5	<.25
06-18-86	3.9	<.30	<.05	<.10	<.10	<.05	.47	<.5	<.25
07-08-86	8.0	<.30	<.05	<.10	<.10	<.05	.81	<.5	<.25
07-30-86	8.3	<.30	<.05	<.10	<.10	<.05	.97	<.5	<.25
08-13-86	7.4	<.30	<.05	<.10	<.10	<.05	.81	<.5	<.25
09-11-86	4.7	<.30	<.05	<.10	<.10	<.05	.48	<.5	<.25
09-22-86	4.0	<.30	<.05	<.10	<.10	<.05	.38	<.5	<.25
10-28-86	<1.2	<.30	<.05	<.10	<.10	<.05	<.25	<.5	<.25
12-16-86	<1.2	<.30	<.05	<.10	<.10	<.05	<.25	<.5	<.25

Appendix A-2. Hydrologic data for surface-water sites sampled during this investigation, April–December 1986—Continued

Big Blue River near Manhattan, Kans.--Continued

Date (month-day-year)	Metribuzin, total recoverable (µg/L)	Endrin, total recoverable (µg/L)	Lindane, total recoverable (µg/L)	Meth-oxychlor, total recoverable (µg/L)	Toxaphene, total recoverable (µg/L)	Sediment suspended (mg/L)	Suspended sediment, fall diameter (% finer than 0.004 mm)	Suspended sediment, sieve diameter (% finer than 0.062 mm)
04-08-86	<0.10	<0.10	<0.025	<0.20	<2	34	--	63
05-07-86	<.10	<.10	<.025	<.20	<2	--	--	--
06-02-86	<.10	<.10	<.025	<.20	<2	33	--	100
06-18-86	<.10	<.10	<.025	<.20	<2	10	--	100
07-08-86	.22	<.10	<.025	<.20	<2	369	90	98
07-30-86	.17	<.10	<.025	<.20	<2	81	--	95
08-13-86	.11	<.10	<.025	<.20	<2	58	--	87
09-11-86	<.10	<.10	<.025	<.20	<2	56	--	98
09-22-86	<.10	<.10	<.025	<.20	<2	30	--	99
10-28-86	<.10	<.10	<.025	<.20	<2	--	--	--
12-16-86	<.10	<.10	<.025	<.20	<2	--	--	--

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