TRAVELTIME AND REAERATION CHARACTERISTICS FOR SALT CREEK BASIN IN NORTHEASTERN ILLINOIS, JUNE–OCTOBER 1995

U.S. GEOLOGICAL SURVEY

Open-File Report 95–771

Prepared in cooperation with the
ILLINOIS ENVIRONMENTAL PROTECTION AGENCY

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Urbana, Illinois
1996

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CONVERSION FACTORS

Multiply	By	To obtain
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
million gallons per day (Mgal/d)	0.04381	cubic meter per second

Temperature in degrees Celcium (°C) can be converted to degrees Fahrenheit (°F) as follows:

$$°F = 9/5\ (°C) + 32$$

SYMBOLS AND UNITS

Abbreviated units in this report:

in hours (h)
micrograms per liter (µg/L)
micrograms per liter per hour (µg/L/h)
milliliters (mL)
per hour (h^{-1})

Symbols and units in this report:

A_c	Area of the observed dye concentration-time response curve	(µg/L/h)
C_d	Observed dye concentration	µg/L
$\overline{C}_g$	Weighted or average plateau propane gas concentration	µg/L
C_p	Observed peak dye concentration	µg/L
d	Subscript denoting downstream	--
i	Integration interval	--
K_p	Propane gas desorption rate coefficient	h^{-1}
$K_{2,20}$	Oxygen absorption or reaeration rate coefficient at 20 °C	h^{-1}
Q	Total stream discharge	ft^3/s
Δt	Numerical integration interval	h
t_c	Traveltime of centroid of dye-response curve	h
t_i	Elapsed time to point i on dye-response curve	h
T_c	Elapsed time to centroid of dye-response curve	h
u	Subscript denoting upstream	--
Y	Stream temperature	°C

Traveltime and Reaeration Characteristics for Salt Creek Basin in Northeastern Illinois, June–October 1995

By Mary J. Turner

Abstract

Traveltime and reaeration measurements were made in the Salt Creek Basin, a tributary to the Des Plaines River, in northeastern Illinois during three study periods from June through October 1995. The measurements were made in representative lengths on three reaches of Salt Creek: upper reach, middle reach, and lower reach. During the measurement periods the streamflows of Salt Creek ranged from 22 to 36 cubic feet per second (ft^3/s) in the upper reach, 48 to 57 ft^3/s in the middle reach, and 52 to 61 ft^3/s in the lower reach. Traveltimes ranged from 2.1 to 2.3, 5.3 to 6.1, and 1.4 to 1.9 hours in the upper, middle, and lower reaches, respectively. Measured reaeration coefficients adjusted to 20 °C ranged from 0.033 to 0.397, 0.011 to 0.036, and 0.115 to 0.306 per hour, in the upper, middle, and lower reaches, respectively. Representative measurements also were made in lengths on two reaches of major tributaries to Salt Creek, Spring Brook and Addison Creek. During the study periods the streamflows of Spring Brook ranged from 2.2 to 2.8 ft^3/s and Addison Creek ranged from 9.6 to 30 ft^3/s. Traveltimes for Spring Brook were 3.7 and 5.0 hours and Addison Creek was 1.6 hours. Measured reaeration coefficients in Spring Brook were 0.093 and 0.218 per hour and Addison Creek were 0.169 and 0.287 per hour.

INTRODUCTION

Reaeration and time of travel studies are commonly conducted to develop predictive equations for estimating reaeration coefficients. The reaeration coefficient is the rate constant for the absorption of oxygen from the atmosphere to the stream, the primary process by which a stream replenishes oxygen consumed by the biodegradation of organic wastes.

The U.S. Geological Survey (USGS), in cooperation with the Illinois Environmental Protection Agency (IEPA), conducted a study in 1995 to determine the traveltime and reaeration characteristics of Salt Creek, a tributary to the Des Plaines River, in northeastern Illinois (fig.1). These characteristics will be applied to a water-quality model, QUAL2E, to analyze the assimilative capacity of Salt Creek. QUAL2E, when fully calibrated and verified, will be used by the IEPA in the development of Phase 1 Total Maximum Daily Load (TMDL) values for the Salt Creek Basin.

Purpose and Scope

The purpose of this report is to describe the reaeration and traveltime data collected for Salt Creek in northeastern Illinois during three periods from June through October 1995. This report describes the study area, gas and dye injection and sampling, reaeration methods, and determination of traveltime and reaeration characteristics for the Salt Creek Basin.

Description of the Study Area

Salt Creek, a tributary to the Des Plaines River,

drains 150 mi^2 in Cook and Du Page Counties in northeastern Illinois (fig.1). The two major tributaries to Salt Creek are Spring Brook and Addison Creek, which drain 14.3 and 23.8 mi^2, respectively. The Salt Creek Basin receives discharges from 19 point sources; only 11, however, are within the boundaries of the reaches considered in this study, eight to Salt Creek, two to Spring Brook, and one to Addison Creek. The 11 point sources have design average discharges which vary from 0.5 to 30 Mgal/d. The study reaches are shown in figure 1 and sites for data collection are listed in table 1.

Three reaches and two tributary reaches of Salt Creek were chosen for determination of traveltime and reaeration coefficients in the Salt Creek Basin. The three reaches of Salt Creek have different channel slopes and are designated as the upper reach from river mile 19.3 to 31.7 (slope of 3.99×10^{-4}), middle reach from river mile 3.6 to 19.3 (slope of 4.03×10^{-4}), and lower reach from river mile 0 to 3.6 (slope of 2.87×10^{-4}). The tributary reaches studied were on Spring Brook (slope of 8.0×10^{-4}) and Addison Creek (slope of 8.0×10^{-4}). A representative length within each reach consisted of an injection site, where dye and propane gas tracers were injected; an upstream sampling site; and a downstream sampling site.

INJECTION, SAMPLING, AND ANALYTICAL METHODS

Propane gas and rhodamine WT dye were injected as tracers in five reaches of the Salt Creek Basin based on the Constant Rate Injection (CRI) methods described in Kilpatrick and others (1989). The dye was injected as a slug at the center of flow. The propane gas was injected continuously through ceramic diffuser plates placed at the center of flow on the streambed with the injection beginning at the same time as the dye injection. Propane gas cylinders equipped with regulators and rotameters (flow meters) were used to inject and monitor the flow of the propane gas. Injection amounts were determined based on the methods described in Kilpatrick and others (1989).

Samples were collected at two sites downstream from the point of injection. The sampling intervals were determined based on the methods described in Kilpatrick and others (1989). Dye samples were collected by dipping a 20 mL vial into the stream near the left bank (16.6 percent of flow), in the center (50 percent of flow), and near the right bank (83.3 percent of flow). All dye samples were analyzed in the Illinois District laboratory based on fluorometric procedures presented by Wilson and others (1986).

Table 1. Time of travel and reaeration data-collection sites in Salt Creek Basin in northeastern Illinois, June-October 1995
[USGS, U.S. Geological Survey: Rd., Road; Ave., Avenue. For each reach, sites are listed in order of injection site, upstream sampling site, and downstream sampling site.]

Reach name	Distance from injection site (feet)	USGS station number	Station name (abbreviated station name)
Upper Salt	0	05531045	Salt Creek at Elk Grove Village, Ill. (Arlington Heights Rd.)
	8,240	05531050	Salt Creek near Wood Dale, Ill. (Devon Ave.)
	12,350	05531060	Salt Creek at Thorndale Avenue near Elk Grove Village, Ill. (Thorndale Ave.)
Middle Salt	0	05531365	Salt Creek at Butterfield Road at Elmhurst, Ill. (Butterfield Rd.)
	4,224	05531390	Salt Creek at Drury Lane at Oakbrook, Ill. (Drury Lane)
	11,986	05531410	Salt Creek at 22nd Street at Oakbrook, Ill. (22nd St.)
Lower Salt (June)	0	05532300	Salt Creek at Brookfield, Ill. (Maple Ave.)
	6,970	05532402	Salt Creek at Logan Avenue near Brookfield, Ill. (Logan Ave.)
	10,613	05532405	Salt Creek at Washington Avenue near Brookfield, Ill. (Washington Ave.)
Lower Salt (Aug., Oct.)	0	05532400	Salt Creek below Diversion Culvert at Brookfield, Ill. (Diversion)
	5,966	05532405	Salt Creek at Washington Avenue near Brookfield, Ill. (Washington Ave.)
	9,609	05532407	Salt Creek at Circle Drive at Brookfield, Ill. (Circle Dr.)
Spring Brook	0	05531110	Spring Brook at Rohlwing Road near Itasca, Ill. (Rohlwing Rd.)
	3,907	05531120	Spring Brook at Valley Road at Itasca, Ill. (Valley Rd.)
	6,705	05531130	Spring Brook at Walnut Avenue at Itasca, Ill. (Walnut Ave.)
Addison Creek	0	05532255	Addison Creek at 25th Avenue at Broadview, Ill. (25th Ave.)
	2,798	05532275	Addison Creek at 19th Avenue at Broadview, Ill. (19th Ave.)
	4,963	05532295	Addison Creek at 18th Avenue at Broadview, Ill. (18th Ave.)

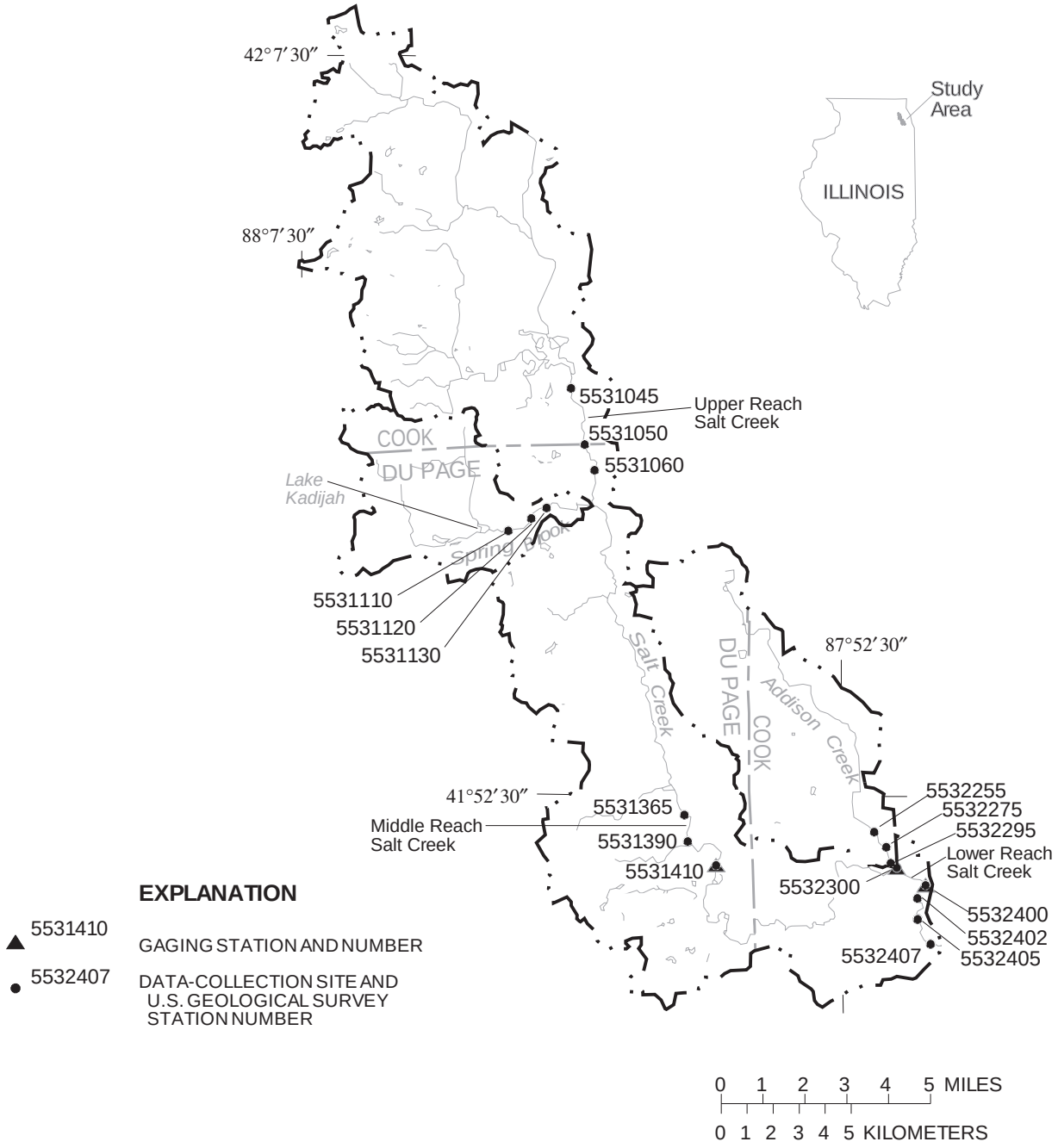

Figure 1. Location of traveltime and reaeration study reaches and data-collection sites in the Salt Creek Basin, northeastern Illinois.

Additionally, selected samples were analyzed in the field to monitor the travel of the dye cloud.

Propane gas samples were collected in pairs at the center of flow with a gas sampler, except at Spring Brook where samples were collected by hand dipping a sample bottle because shallow water depths did not allow the use of the gas sampler. The gas sampler holds a pair of 40 mL sample bottles and is designed such that the sample bottle is flushed several times in the process of filling. While the sample bottle was still submerged, 1 mL of formalin was added to prevent biodegradation of the sample. The sample was capped with a septum, Teflon PTFE-faced, silicone seal cap and inspected for air bubbles. Samples with air bubbles were discarded. Samples were then protected against drastic temperature change and shipped to the USGS Water Quality Laboratory in Ocala, Fla. for propane gas concentration analysis. The propane gas samples were collected on a schedule set as a result of field analysis of the dye curve. As the dye concentrations approached background concentrations, the propane gas, theoretically, reached the plateau concentration and samples at the plateau were collected.

REAERATION MEASUREMENTS

Three reaeration measurements were made on each reach on Salt Creek during low-flow periods in June, August–September, and October, and two reaeration measurements were made on the tributary reaches during the study period. Spring Brook was measured in August–September and October; Addison Creek was measured in June and August–September. Discharge measurements were made at each site, dye and propane gas were injected, and samples for dye and propane gas concentration analysis were collected at sites downstream from the injection. Water temperature was noted except in June. Water temperatures in June were estimated to be 20 °C based on data from a nearby streamflow-gaging station during this period. A summary of the data collected at each site is in table 2.

Upper Reach Salt Creek

The injection site for the upper reach of Salt Creek was at Salt Creek at Elk Grove Village, Ill., (05531045). Crews collected dye and propane gas samples at the upstream sampling site, Salt Creek near Wood Dale, Ill. (05531050) and the downstream sampling site, Salt Creek at Thorndale Avenue near Elk Grove Village, Ill. (05531060). The leading edge of the dye cloud was missed during the June measurement at the downstream sampling site and the dye curve was extrapolated for that period. Also, the discharge increased from 22 ft^3/s at 0930 hours to 32 ft^3/s at 1600 hours. Because propane gas samples were collected, both at the upstream and downstream sampling sites, after 1700 hours, 32 ft^3/s was used as the discharge in the calculation of the June reaeration coefficient. Streamflow ranged from 22 to 36 ft^3/s and water temperatures from 18 to 25 °C in the reach during the three measurement periods.

Middle Reach Salt Creek

In the middle reach of Salt Creek the injection site was Salt Creek at Butterfield Road at Elmhurst, Ill. (05531365), the upstream sampling site was Salt Creek at Drury Lane at Oakbrook, Ill. (05531390), and the downstream sampling site was Salt Creek at 22nd Street at Oakbrook, Ill. (05531410). The leading edge of the dye cloud was missed at the upstream sampling site during the June measurement and the dye curve was extrapolated for that period. Streamflow ranged from 48 to 57 ft^3/s and water temperatures from 16 to 26 ×××°C in the reach during the three measurement periods.

Lower Reach Salt Creek

The injection site for the lower reach of Salt Creek was at Salt Creek at Brookfield, Ill. (05532300) for the June measurement with Salt Creek at Logan Avenue near Brookfield , Ill. (05532402), and Salt Creek at Washington Avenue near Brookfield, Ill. (05532405) as upstream and downstream sampling sites. The leading edge of the dye-response curve at Washington Avenue was missed and was extrapolated for the June measurement. During this measurement, the flow dropped about 25 ft^3/s between the injection site and the upstream sampling site. A diversion to the Des Plaines River was causing the loss of flow. The injection site was moved to below the diversion at Salt Creek below Diversion Culvert at Brookfield, Ill. (05532400), for the August–September and October measurements. This made the Logan Avenue site too close to the injection for an accurate upstream reaeration measurement. Therefore, the Washington

Table 2. Site descriptions and data summary for time of travel and reaeration measurements for Salt Creek Basin reaches, northeastern Illinois, June–October 1995.

[Rd., Road; Ave., Avenue; USGS, U.S. Geological Survey; ID, identification; ft, feet; na, not applicable; mL, milliliters; ft^3/h, cubic feet per hour; --, no data; shaded area, values are calculated using upstream and downstream data; ft^3/s, cubic feet per second; nc, not calculated; values in parentheses are extrapolated from response curves]

Site Information and Variables: Q, total stream discharge, in cubic feet per second (ft^3/s); A_c, area of the observed dye concentration-time response curve, in micrograms per liter per hour ($\mu g/L/h^{-1}$); C_p, observed peak dye concentration, in micrograms per liter ($\mu g/L$); c_g, weighted or propane average plateau gas concentration, in micrograms per liter ($\mu g/L$); T_c, elapsed time to centroid of dye-response curve, in hour (h); Y, stream temperature, in degree Celcius ($^\circ C$); K_p, propane gas desorption rate coefficient in per hour (h^{-1}); $K_{2,20}$, oxygen absorption or reaeration rate coefficient at $20^\circ C$ in per hour (h^{-1}).

Sampling date	Site information and variables	Injection and sampling locations		
		Injection	Upstream	Downstream
	Salt Creek Upper Reach			
June 26	Site Name	Arlington Heights Rd.	Devon Ave.	Thorndale Ave.
	USGS Site ID Number	05531045	05531050	05531060
	Stream length from injection site (ft)	0	8,240	12,350
	Time of rhodamine WT20 dye injection	09:48	na	na
	Amount of rhodamine WT20 dye injection (mL)	75	na	na
	Propane gas injection rate (ft^3/h)	34	na	na
	Q	nc	22	32
	A_c	na	8.3	(6.2)
	C_p	na	6.0	3.6
	c_g	na	65	61.8
	T_c	na	4.8	(6.9)
	Y[1]		--	
	Kp[1]		0.026	
	[1]$K_{2,20}$		.033	
August 29	Site Name	Arlington Heights Rd.	Devon Ave.	Thorndale Ave.
	USGS Site ID Number	05531045	05531050	05531060
	Stream length from injection site (ft)	0	8,240	12,350
	Time of rhodamine WT20 dye injection	09:15	na	na
	Amount of rhodamine WT20 dye injection (mL)	150	na	na
	Propane gas injection rate (ft^3/h)	30	na	na
	Q	nc	36	35
	A_c	na	12.2	12.2
	C_p	na	10.5	8.2
	c_g	na	49	43.5
	T_c	na	4.15	6.25
	Y[1]		24.8	
	Kp[1]		.071	
	[1]$K_{2,20}$		.088	
October 17	Site Name	Arlington Heights Rd.	Devon Ave.	Thorndale Ave.
	USGS Site ID Number	05531045	05531050	05531060
	Stream length from injection site (ft)	0	8,240	12,350
	Time of rhodamine WT20 dye injection	08:10	na	na
	Amount of rhodamine WT20 dye injection (mL)	150	na	na
	Propane gas injection rate (ft^3/h)	30	na	na
	Q	nc	35	31
	A_c	na	10.5	21
	C_p	na	15.2	12.1
	c_g	na	56	33
	T_c	na	4.03	6.33
	Y[1]		18.4	
	Kp[1]		.275	
	[1]$K_{2,20}$		.397	

Table 2. Site descriptions and data summary for time of travel and reaeration measurements for Salt Creek Basin reaches, northeastern Illinois, June–October 1995—Continued

Sampling date	Site information and variables	Injection and sampling locations		
		Injection	Upstream	Downstream
	Salt Creek Middle Reach			
June 27	Site Name	Butterfield Rd.	Drury Lane	22nd St.
	USGS Site ID Number	05531365	05531390	05531410
	Stream length from injection site (ft)	0	4,224	11,986
	Time of rhodamine WT20 dye injection	09:12	na	na
	Amount of rhodamine WT20 dye injection (mL)	175	na	na
	Propane gas injection rate (ft^3/h)	15	na	na
	Q	nc	47.5	54
	A_c	na	(9.9)	9.4
	C_p	na	(32)	8.6
	c_g	na	29.0	24.2
	T_c	na	(1.5)	7.2
	Y^1		--	
	Kp^1		0.008	
	$^1K_{2,20}$		.011	
August 30	Site Name	Butterfield Rd.	Drury Lane	22nd St.
	USGS Site ID Number	05531365	05531390	05531410
	Stream length from injection site (ft)	0	4,224	11,986
	Time of rhodamine WT20 dye injection	08:30	na	na
	Amount of rhodamine WT20 dye injection (mL)	150	na	na
	Propane gas injection rate (ft^3/h)	15	na	na
	Q	nc	54	52
	A_c	na	8.9	7.7
	C_p	na	19.4	5.2
	c_g	na	34.7	30.7
	T_c	na	1.4	6.7
	Y^1		25.6	
	Kp^1		.030	
	$^1K_{2,20}$		.036	
October 18	Site Name	Butterfield Rd.	Drury Lane	22nd St.
	USGS Site ID Number	05531365	05531390	05531410
	Stream length from injection site (ft)	0	4,224	11,986
	Time of rhodamine WT20 dye injection	08:05	na	na
	Amount of rhodamine WT20 dye injection (mL)	150	na	na
	Propane gas injection rate (ft^3/h)	15	na	na
	Q	nc	51	57
	A_c	na	13.5	11.4
	C_p	na	30	7.4
	c_g	na	34.3	30.9
	T_c	na	1.42	7.52
	Y^1		15.9	
	Kp^1		.018	
	$^1K_{2,20}$		.028	

Table 2. Site descriptions and data summary for time of travel and reaeration measurements for Salt Creek Basin reaches, northeastern Illinois, June–October 1995—Continued

Sampling date	Site information and variables	Injection and sampling locations		
		Injection	Upstream	Downstream
	Salt Creek Lower Reach			
June 28	Site Name	Maple Ave.	Logan Ave.	Washington Ave.
	USGS Site ID Number	05532300	05532402	05532405
	Stream length from injection site (ft)	0	6,970	10,613
	Time of rhodamine WT20 dye injection	08:45	na	na
	Amount of rhodamine WT20 dye injection (mL)	215	na	na
	Propane gas injection rate (ft^3/h)	15	na	na
	Q	nc	80	83
	A_c	na	10.0	(7.7)
	C_p	na	12.7	(9)
	c_g	na	17.5	12.9
	T_c	na	2.45	3.85
	Y^1		--	
	Kp^1		0.188	
	$^1K_{2,20}$		.261	
August 31	Site Name	Diversion	Washington Ave.	Circle Drive
	USGS Site ID Number	05532400	05532405	05532407
	Stream length from injection site (ft)	0	5,996	9,609
	Time of rhodamine WT20 dye injection	08:50	na	na
	Amount of rhodamine WT20 dye injection (mL)	150	na	na
	Propane gas injection rate (ft^3/h)	15	na	na
	Q	nc	61	60
	A_c	na	7.9	7.8
	C_p	na	16.1	8.7
	c_g	na	45.7	39.3
	T_c	na	2.17	3.87
	Y^1		26.5	
	Kp^1		.097	
	$^1K_{2,20}$		.115	
October 19	Site Name	Diversion	Washington Ave.	Circle Drive
	USGS Site ID Number	05532400	05532405	05532407
	Stream length from injection site (ft)	0	5,996	9,609
	Time of rhodamine WT20 dye injection	08:33	na	na
	Amount of rhodamine WT20 dye injection (mL)	150	na	na
	Propane gas injection rate (ft^3/h)	15	na	na
	Q	nc	56	52
	A_c	na	12.5	12.4
	C_p	na	15.2	10.1
	c_g	na	42.6	31.2
	T_c	na	2.55	4.45
	Y^1		15.3	
	Kp^1		.197	
	$^1K_{2,20}$		.306	

Table 2. Site descriptions and data summary for time of travel and reaeration measurements for Salt Creek Basin reaches, northeastern Illinois, June–October 1995—Continued

Sampling date	Site information and variables	Injection and sampling locations		
		Injection	Upstream	Downstream
	Spring Brook			
September 1	Site Name	Rohlwing Rd.	Valley Rd.	Walnut Ave.
	USGS Site ID Number	05531110	05531120	05531130
	Stream length from injection site (ft)	0	3,907	6,705
	Time of rhodamine WT20 dye injection	08:30	na	na
	Amount of rhodamine WT20 dye injection (mL)	10	na	na
	Propane gas injection rate (ft^3/h)	15	na	na
	Q	nc	2.33	2.45
	A_c	na	16.6	15.4
	$\mathcal{L}_p$	na	8.7	5.5
	c_g	na	240	(106)
	T_c	na	5.4	10.4
	Y^1		23.6	
	Kp^1		.171	
	$^1K_{2,20}$		.218	
October 16	Site Name	Rohlwing Rd.	Valley Rd.	Walnut Ave.
	USGS Site ID Number	05531110	05531120	05531130
	Stream length from injection site (ft)	0	3,907	6,705
	Time of rhodamine WT20 dye injection	07:09	na	na
	Amount of rhodamine WT20 dye injection (mL)	10	na	na
	Propane gas injection rate (ft^3/h)	17.5	na	na
	Q	nc	2.15	2.83
	A_c	na	15.6	13.7
	$\mathcal{L}_p$	na	11.6	6.6
	c_g	na	227	140
	T_c	na	4.25	7.95
	Y^1		11.7	
	Kp^1		.055	
	$^1K_{2,20}$		.093	

Table 2. Site descriptions and data summary for time of travel and reaeration measurements for Salt Creek Basin reaches, northeastern Illinois, June–October 1995—Continued

Sampling date	Site information and variables	Injection and sampling locations		
		Injection	Upstream	Downstream
	Addison Creek			
June 29	Site Name	25th Ave.	19th Ave.	18th Ave.
	USGS Site ID Number	05532255	05532275	05532295
	Stream length from injection site (ft)	0	2,798	4,963
	Time of rhodamine WT20 dye injection	08:15	na	na
	Amount of rhodamine WT20 dye injection (mL)	36	na	na
	Propane gas injection rate (ft^3/h)	15	na	na
	Q	nc	11.7	9.6
	A_c	na	7.2	5.9
	$\mathcal{L}_p$	na	13.6	7.1
	c_g	na	56.3	48.8
	T_c	na	1.85	3.45
	Y[1]		--	
	Kp[1]		0.206	
	$^1K_{2,20}$		.287	
August 28	Site Name	25th Ave.	19th Ave.	18th Ave.
	USGS Site ID Number	05532255	05532275	05532295
	Stream length from injection site (ft)	0	2,798	4,963
	Time of rhodamine WT20 dye injection	09:30	na	na
	Amount of rhodamine WT20 dye injection (mL)	50	na	na
	Propane gas injection rate (ft^3/h)	10	na	na
	Q	nc	[2]30.3	[2]29.3
	A_c	na	11.5	7.9
	$\mathcal{L}_p$	na	16.5	9.8
	c_g	na	43.1	36.6
	T_c	na	3.6	5.2
	Y[1]		24.8	
	Kp[1]		.135	
	$^1K_{2,20}$		.169	

[1]Calculated using upstream and downstream data.

[2]Discharge was measured in the early morning of August 28, 1996. Upstream discharge was 3.75 ft^3/s and downstream discharge was 4.1 ft^3/s. Propane samples were collected during the higher discharge; therefore, the higher discharge values are used in the calculation of reaeration values.

Avenue site was made the upstream sampling site. Salt Creek at Circle Drive at Brookfield, Ill. (05532407) was added as the downstream sampling site. Streamflow ranged from 80 to 83 ft^3/s in June; streamflow ranged from 52 to 61 ft^3/s and water temperatures from 15 to 27 °C in the reach for the August–September and October periods.

Spring Brook

Originally, a reach of Spring Brook upstream from Lake Kadijah (fig.1) was chosen for measurement of reaeration. Flow conditions during the June measurement were such that the tracers were not detected downstream. The reach was injected and observed again on July 19 and the tracers again were not detected downstream. For the August–September measurement, the Spring Brook reach was moved to downstream from Lake Kadijah. Dye was injected at Spring Brook at Rohlwing Road near Itasca, Ill. (05531110) and samples were collected downstream at Spring Brook at Valley Road at Itasca, Ill. (05531120), and at Spring Brook at Walnut Avenue at Itasca, Ill. (05531130). Although traveltimes were greater than estimated, the tracers were observed at the downstream sites so that an analysis of traveltime and reaeration could be made. During the August–September measurement, the propane gas sampling was terminated too early at the downstream sampling site. The propane gas-plateau concentration was extrapolated based on the extrapolated dye-response curve. The October measurement also was made in this reach of Spring

Brook. Streamflow ranged from 2.2 to 2.8 ft^3/s and water temperatures from 12 to 24 °C in the reach during the two measurement periods.

Addison Creek

The injection site on the Addison Creek Reach was at Addison Creek at 25th Avenue at Broadview, Ill. (05532255). The upstream sampling site was at Addison Creek at 19th Avenue at Broadview, Ill. (05532275) and the downstream sampling site was at Addison Creek at 18th Avenue at Broadview, Ill. (05532295). Rain fell for a short time in the late morning during the August–September reaeration measurement causing stage to fluctuate 0.59 ft and discharge to increase from 4 ft^3/s to 30 ft^3/s. Water temperature was 25 °C at this time. During the June measurement, stage fluctuated 0.22 ft but corresponding discharge measurements were not made. No rain fell during the June measurement and the cause for the fluctuation is not known.

TRAVELTIME CHARACTERISTICS

The traveltime for the flow in a reach is defined as the difference in elapsed time of the centroids of the dye curves (Kilpatrick and others, 1989). The traveltime rates were calculated by numerically integrating the dye-response curves at each sample site in each reach and taking the difference between the centroid traveltimes. At sites where sufficient cross-sectional dye response curves were available, the left bank, center, and right bank dye response curves were integrated and the centroid traveltimes were averaged for a site traveltime. The traveltime results are listed in table 3. At three sites in three reaches during the June measurement, samples were not collected to document the leading edge of the dye-response curve. The curves were extrapolated to calculate the lapsed time to centroid.

Table 3. Summary of time-of-travel data for Salt Creek Basin reaches, northeastern Illinois, June–October 1995

[shaded area shows: t_c, traveltime of centroid of dye-response curve, in hours; values in parentheses were calculated with extrapolated dye-response curve; --, no data]

Reach	Location	Time of dye centroid and traveltime of centroid (hours)		
		June	August–September	October
Upper Salt Creek	Devon Avenue	14.6	13.4	12.2
	Thorndale Avenue	(16.7)	15.5	14.5
	t_c	2.1	2.1	2.3
Middle Salt Creek	Drury Lane	(10.7)	9.9	9.5
	Cermak Avenue	16.4	15.2	15.6
	t_c	5.7	5.3	6.1
Lower Salt Creek[1]	Logan	11.2	--	--
	Washington Avenue	(12.6)	--	--
	t_c	1.4	--	--
Lower Salt Creek[2]	Washington Avenue	--	11.0	11.1
	Circle Drive	--	12.7	13.0
	t_c	--	1.7	1.9
Spring Brook	Valley Road	--	13.9	11.4
	Irving Park Road	--	18.9	15.1
	t_c	--	5.0	3.7
Addison Creek	19th Avenue	10.1	13.1	--
	18th Avenue	11.7	14.7	--
	t_c	1.6	1.6	--

[1]June measurement length.
[2]August–September and October measurement length.

REAERATION CHARACTERISTICS

The reaeration coefficients were calculated based on the constant-rate injection method for one-dimensional dispersion of Kilpatrick and others (1989, p. 37–43). The dye and propane gas concentration data were plotted for both upstream and downstream sections for each reach during each measurement period. An example data plot is shown in figure 2. An example of a site where the data needed to be extrapolated because of the lack of samples to document the leading edge of the dye-response curve is shown in figure 3. An estimated value for the propane gas desorption rate coefficient was calculated with

$$K_p = \frac{1}{t_c} \ln \frac{(\bar{c}_g Q)_u}{(\bar{c}_g Q)_d} ,$$

and used as a basis for selecting trial values of K_p in

$$\left[\frac{(\bar{c}_g Q)_u}{(\bar{c}_g Q)_d}\right] = \frac{\left[\sum_{i=1}^{N} \frac{C_d \Delta t}{A_c e^{K_p t_i}}\right]_u}{\left[\sum_{i=1}^{N} \frac{C_d \Delta t}{A_c e^{K_p t_i}}\right]_d} ,$$

where,

K_p = Propane gas desorption rate coefficient,
C_d = Observed dye concentration,
$\bar{c}_g$ = Weighted or average plateau propane gas concentration,
Δt = Numerical integration interval,
Q = Total stream discharge,
A_c = Area of the observed dye concentration-time response curve,
u = subscript denoting upstream,
d = subscript denoting downstream,
t_c = traveltime of centroid of dye-response curve,
t_i = Elapsed time to point i on dye-response curve,
i = Integration interval.

where the dye-response curves are numerically integrated. The oxygen absorption rate coefficient is then calculated as

$$K_2 = 1.39 K_p ,$$

and adjusted to 20 °C using

$$K_{2,20} = K_2 (1.0241)^{(20 - Y)} ,$$

where Y is the stream temperature. Reaeration values calculated from these equations are listed in table 4.

Table 4. Summary of calculated reaeration rate coefficients for Salt Creek Basin reaches, northeastern Illinois, June–October 1995
[$_{2,20}$, oxygen absorption or reaeration rate coefficient at 20 °Celcius; --, no data]

Reach	Sampling date	Reaeration rate, $K_{2,20}$ (per hour)
Upper Salt Creek	June 26[1]	0.033
	August 29	.088
	October 17	.397
Middle Salt Creek	June 27[1]	.011
	August 30	.036
	October 18	[2].028
Lower Salt Creek[3]	June 28[1]	.261
	August 31	--
	October 19	--
Lower Salt Creek[4]	June 28	--
	August 31	.115
	October 19	.306
Spring Brook	September 1	.218
	October 16	.093
Addison Creek	June 29[1]	.287
	August 28	.169

[1]Temperature data not available. Assumed 20 °C based on data at a nearby streamgaging station.
[2]Calculated with the average of the upstream and downstream sampling-site discharge measurements.
[3]Lower reach, measurement length used in June.
[4]Lower reach, measurement length used in August–September.

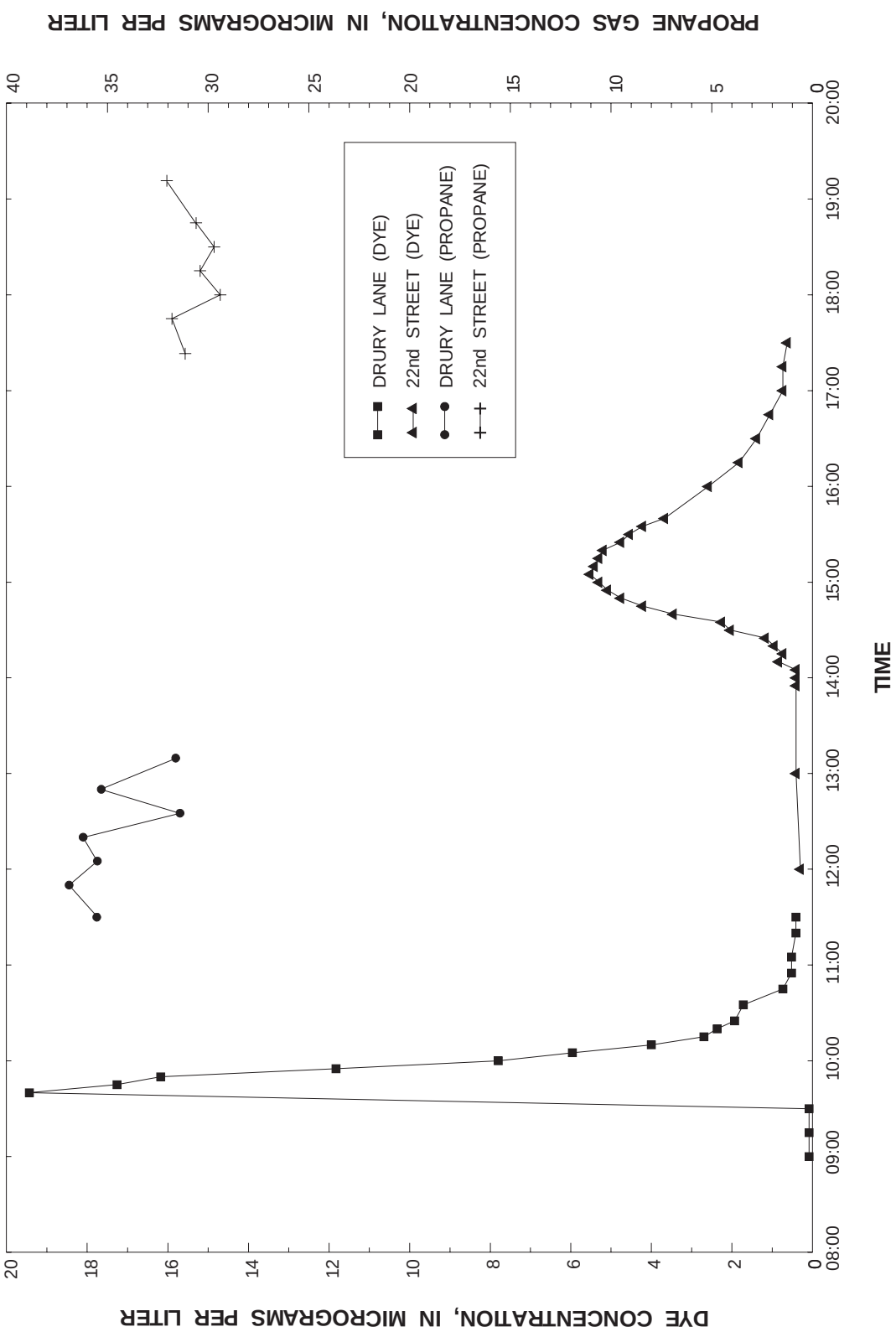

Figure 2. Example of concentration-time data for the gas and dye tracers.

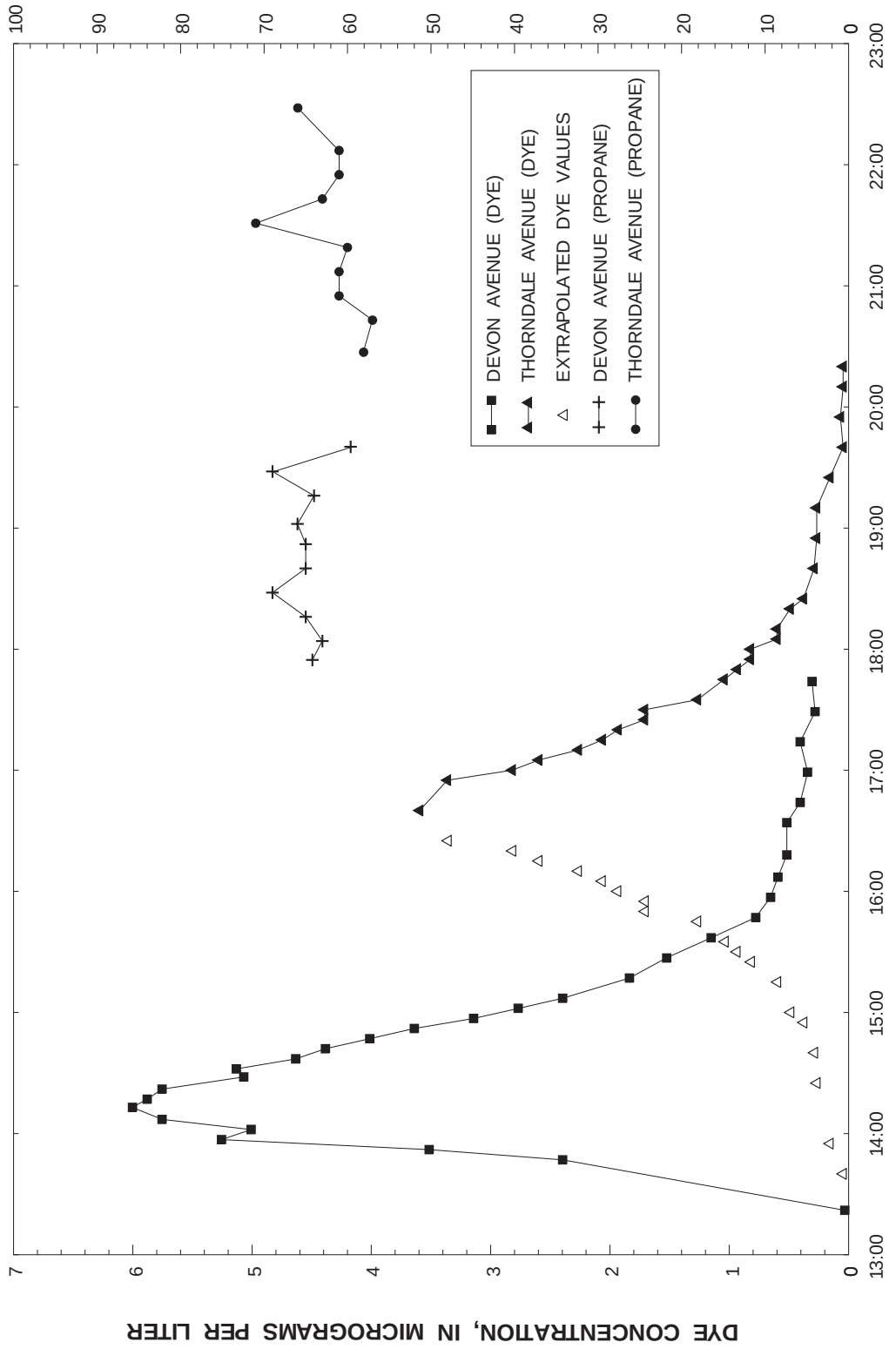

Figure 3. Example of concentration-time data for the gas and dye tracers where the dye-response curve is extrapolated.

SUMMARY

The U.S. Geological Survey (USGS), in cooperation with the Illinois Environmental Protection Agency (IEPA), conducted a study in 1995 to determine traveltime and reaeration rates in the Salt Creek Basin in northeastern Illinois. Traveltime and reaeration measurements were made during three low-flow periods from June–October 1995 on three reaches of Salt Creek and on two reaches on tributaries to Salt Creek—Spring Brook and Addison Creek. Rhodamine WT dye and propane gas were used as tracers in the reaches. Each reach consisted of an injection site, an upstream sampling site, and a downstream sampling site. The movement of the dye cloud was observed and used to determine the sampling schedule for the propane gas.

Traveltimes were calculated by taking the difference between the centroids of the dye-response curves. Traveltimes ranged from 2.1 to 2.3 hours, 5.3 to 6.1 hours, and 1.4 to 1.9 hours in the upper, middle, and lower reaches, respectively. Traveltime on Spring Brook ranged from 3.7 to 5.0 hours and traveltime on Addison Creek was 1.6 hours.

Reaeration coefficients were calculated based on the constant-rate injection method of Kilpatrick and others (1989). The reaeration coefficients ranged from 0.033 to 0.397, 0.011 to 0.036, and 0.115–0.306 hr^{-1} on the upper, middle, and lower reaches, respectively, and from 0.093–0.218 and 0.169–0.287 hr^{-1} on Spring Brook and Addison Creek.

REFERENCES CITED

Kilpatrick, F.A., and others, 1989, Determination of stream reaeration coefficients by use of tracers: U.S. Geological Survey Techniques of Water–Resources Investigations, book 3, chap. A18, 52 p.

Wilson, J.F., Jr., and others, 1986, Fluorometric procedures for dye tracing: U.S. Geological Survey Techniques of Water–Resources Investigations, book 3, chap. A12, 34 p.