TRAVELTIME AND DISPERSION DATA, INCLUDING ASSOCIATED DISCHARGE AND WATER-SURFACE ELEVATION DATA, KANAWHA RIVER, WEST VIRGINIA, 1991

By Jeffrey B. Wiley

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TRAVELTIME AND DISPERSION DATA, INCLUDING ASSOCIATED DISCHARGE AND WATER-SURFACE ELEVATION DATA, KANAWHA RIVER, WEST VIRGINIA, 1991

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ABSTRACT

This report presents results of a study by the U.S. Geological Survey, in cooperation with the Virginia Environmental Endowment, Marshall University Research Corporation, and the West Virginia Department of Environmental Protection, to evaluate traveltime of a soluble dye on the Kanawha River.

The Kanawha River originates in south-central West Virginia and flows northwestward to the Ohio River. Knowledge of traveltime and dispersion of a soluble dye could help river managers mitigate effects of an accidental spill.

Traveltime and dispersion data were collected from June 20 through July 4, 1991, when river discharges decreased from June 24 through July 3, 1991. Daily mean discharges decreased from 5,540 ft^3/s on June 24 to 2,790 ft^3/s on July 2 at Kanawha Falls and from 5,680 ft^3/s on June 24 to 3,000 ft^3/s on July 2 at Charleston. Water-surface elevations in regulated pools indicated a loss of water storage during the period.

A spill at Gauley Bridge under similar streamflow conditions of this study is estimated to take 15 days to move beyond Winfield Dam. Estimated time of passage (elapsed time at a particular location) at Marmet Dam and Winfield Dam is approximately 2.5 days and 5.5 days, respectively. The spill is estimated to spend 12 days in the Winfield pool.

INTRODUCTION

The Kanawha River originates at the confluence of the New River and Gauley River at Gauley Bridge in south-central West Virginia. From Gauley Bridge, the Kanawha River flows northwest through West Virginia to the Ohio River at Point Pleasant, West Virginia (fig. 1).

The Kanawha River provides water for municipalities and industries, and the river is used for transportation and recreation. Municipal and industrial intakes and outflows are scattered throughout the study area. Chemical-manufacturing plants are located along the upper two-thirds of the river. The river is used to transport chemical-manufacturing materials and coal from the regional coal fields. Recreational boating and fishing are common along the entire river.

Government and industry have successfully cooperated during the past 20 to 25 years to improve water quality (water quality had previously decreased because of municipal and industrial pollution). Water quality can be adversely affected if a contaminant is accidentally spilled. An accidental spill is possible during transportation of chemicals and toxic waste by pipeline, rail, highway, or barge on and near the river and its tributaries. Knowledge of the movement of a spill can help to minimize effects for private and industrial water users. For example, water intakes could be closed, and fishing and recreational uses could be restricted. Traveltime and dispersion data can help river managers to mitigate effects of an accidental spill of a soluble contaminant on river-water quality. Careful management of area dams could be used to change the characteristics of the contaminant cloud. Furthermore, these data can be used to calibrate or verify a water-quality transport model. This study was done in cooperation with the Virginia Environmental Endowment, Marshall University Research Corporation, and the West Virginia Department of Environmental Protection.

Purpose and Scope

This report presents traveltime and dispersion data for the Kanawha River from June 24 through July 3, 1991, when discharges at Charleston ranged from 5,680 ft^3/s on June 24 to 3,000 ft^3/s on July 2, and discharge and water-surface elevation data from June 20 through July 4. The study area is the main stem of the Kanawha River and 4.6 mi of the New River (from the mouth of the New River to Hawks Nest Dam).

Description of Study Area

The Kanawha River originates at the confluence of the Gauley River and New River at Gauley Bridge (fig. 1). Gauley Bridge is located 96.6 river miles (RM) upstream from the mouth of the Kanawha River. The Gauley River has a drainage area of 1,414 mi^2 at the mouth (Mathes and others, 1982), and is regulated by Summersville Dam. The New River has a drainage area of 6,943 mi^2. The New River is regulated by Claytor Dam in Virginia, and Bluestone Dam and Hawks Nest Dam in West Virginia.

Hawks Nest Dam is located 4.6 mi upstream from the mouth of the New River as measured through the Hawks Nest Aqueduct (Erwin, 1986). Hawks Nest Aqueduct is a 3.1-mi tunnel, dropping 162 ft, that circumvents approximately 5 mi of the New River. The tunnel, constructed between 1930 and 1932, has inside diameters between 31 and 46 ft. Part of the tunnel is lined with concrete, part is lined with steel, and part is unlined (Cherniack, 1986).

The Kanawha River has a drainage area of 12,233 mi^2 at the mouth. Tributaries with drainage areas greater than 50 mi^2 located between Gauley Bridge (RM 96.6) and the mouth (RM 0.0) are shown in figure 1, and include: Paint Creek, 123 mi^2, at RM 80.6; Cabin Creek, 72.7 mi^2, at RM 74.5; Elk River, 1,533 mi^2, at RM 58.0; Coal River, 892 mi^2, at RM 45.7; Pocatalico River, 356 mi^2, at RM 39.2; Hurricane Creek, 76.5 mi^2, at RM 28.9; Eighteenmile Creek, 77.9 mi^2, at RM 18.6; and Thirteenmile Creek, 77.9 mi^2, at RM 11.9. Elk River is the only tributary that is regulated (by Sutton Dam).

Kanawha Falls is located approximately 1.4 mi downstream from the confluence of the Gauley and New Rivers (fig. 1). A diversion dam occupies part of the Kanawha River at this

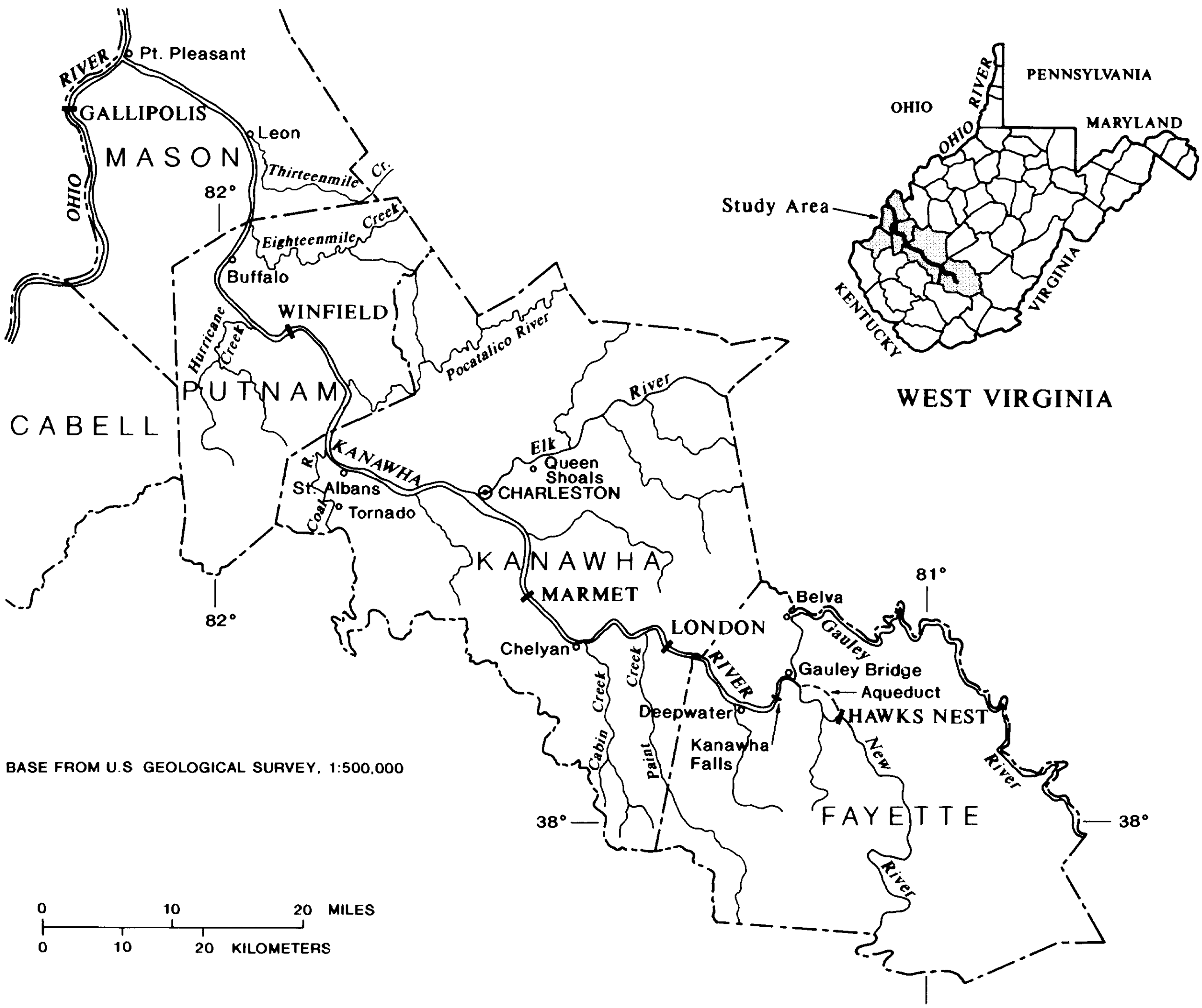

Figure 1.-Location of the Kanawha River study area (Modified from Appel, 1991, p. 3.)

point, forcing additional streamflow across a natural 8-ft falls. Low-head turbines have been installed in a powerhouse adjacent to the falls.

The river flows freely downstream for approximately the next 5 mi until it reaches a series of navigation pools regulated by London, Marmet, Winfield, and Gallipolis Dams. London (RM 82.8), Marmet (RM 67.7), and Winfield (RM 31.1) Dams are submerged weirs with tainter gates, and include navigation locks on the right bank and low-head turbines in a powerhouse on the left bank (U.S. Army Corps of Engineers, 1989). The Gallipolis Dam is on the

Ohio River, approximately 5 mi downstream from the mouth of the Kanawha River, and regulates streamflow in the lower Kanawha River (U.S. Army Corps of Engineers, 1990).

Previous Study

Traveltime and dispersion data were collected for this study area in August and October 1989 (Appel, 1991). In August 1989, dye was injected at Winfield Dam when river discharge was 4,500 ft^3/s, and water samples were collected at locations between Winfield Dam and the mouth of the Kanawha River. In October 1989, dye was injected at Marmet Dam, London Dam, and Hawks Nest Aqueduct when river discharge ranged from 8,500 ft^3/s to 12,500 ft^3/s at Kanawha Falls and from 10,000 ft^3/s to 13,000 ft^3/s at Charleston. Water samples were collected at locations between Hawks Nest Aqueduct and Winfield Dam. Traveltime and dispersion data for the 1989 dye measurements were compiled from analysis of water samples for dye concentration.

Acknowledgments

The author wishes to thank the U.S. Army Corps of Engineers for regulating discharges, providing river-discharge forecasts, and allowing access to river-structure properties. Thanks also goes to the Elkem Metals Company for allowing access to Hawks Nest Dam, and to the Appalachian Power Company for operating low-head turbines at dam structures to help with dye injections and ensuring steady discharges.

TRAVELTIME AND DISPERSION DATA

Traveltime and dispersion are two properties of the movement of water in a river. Horizontal and vertical velocity distributions, eddies, pools, and river bends are some characteristics of a river that affect traveltime and dispersion. River structures, such as bridges and dams, could also affect traveltime and dispersion. Traveltime and dispersion can be affected when regulation at a dam results in holding or releasing more water than is flowing into a controlled pool. Traveltime and dispersion in the general area of the structure can be affected if flow characteristics through the structure change because of changing gate settings and lockages.

Collection Methods

Measurements of traveltime and dispersion of a conservative-dye tracer are used to estimate the movement of water and waterborne solutes in a river system. Measurement techniques are well documented (Kilpatrick and Wilson, 1989; Hubbard and others, 1982). Usually, a fluorescent dye is injected into the river. Water samples are collected at various locations downstream, beyond the distance required for horizontal and vertical mixing. Methods of water-sample analysis have been described by Wilson and others (1986).

A slight modification of the standard procedure was employed for this study. A fluorometer was calibrated by diluting the dye in a three-step procedure to a 100 μg/L working solution, and diluting the working solution into various concentrations expected during the study. A dye lot with the specific gravity of 1.19 is used in the standard procedure. Specific gravity of the dye used in this study was 1.105. In the standard procedure, 2,068 milliliters (mL) of water and 20 mL of dye are mixed in the first step of the three-step process to prepare the 100 μg/L working solution. In this study, 1,191 mL of water were used in the first step to compensate for the differences in specific gravity.

Slug injections in the Kanawha River can require more than 20 mi to mix completely (from equations presented in Kilpatrick and Wilson, 1989). For this reason, all flows at lock-and-dam structures (except for leakage through the structure and normal lockages of river traffic) were routed through the turbines. By routing flows through the turbines, the stream width is temporarily reduced and the river turbulence is increased. Dye was injected as a slug at the upstream face of the dam in front of the turbine gates. This dye-injection technique distributed dye across the entire river within approximately 1 to 2 mi (visual inspection by author), therefore reducing the mixing length. The slug injections at Marmet and London were 200 lb and 75 lb of 20-percent solution of rhodamine-WT dye, respectively.

Dye injection at the location farthest upstream was at the upstream face of the gates that regulate flows into Hawks Nest Aqueduct at Hawks Nest Dam on the New River. All flows in the New River were routed through the tunnel, except for approximately 100 ft^3/s necessary to maintain water quality in the 5 mi of river circumvented by the tunnel. The slug injection at this location was 100 lb of 20-percent solution of rhodamine-WT dye.

Selected river locations are identified in table 1, including those where water samples were collected. Dye concentrations of water samples are presented in tables 5 through 7, which are found at the end of report.

Traveltime

Time-concentration curves were developed to identify traveltime and dispersion of dye injections (figs. 2-4). Traveltime of the leading edge, peak concentration, and trailing edge at locations for each dye injection can be determined from these graphs and from the data given in table 2. Reading from the X-axis of figure 2, the leading edge of the dye cloud produced from the slug injection at Hawks Nest arrived at London Dam approximately 35 hours later and at Chelyan approximately 69 hours later (traveltimes of peak concentration and trailing edge can be determined similarly). Traveltimes for the injections at London and Marmet Dams can be determined from figure 3 and figure 4, respectively.

Mixing length of the river was reduced by injecting dye upstream from the turbines. This procedure did not mix the dye completely at the injection location, and traveltimes are affected to locations downstream until complete mixing is achieved. Much of the effect of incomplete mixing can be accounted for when sample and injection locations are overlapped. Cumulative traveltimes are computed that assume only complete mixing (table 2). Cumulative traveltimes

Table 1.--*Distance to selected locations in the study area*

(Modified from Appel, 1991, p. 6)

Location	Distance, in river miles upstream from the mouth of the Kanawha River
Mouth of Kanawha River	0.0
Point Pleasant, Highway 2 bridge	.1
Confluence of Thirteenmile Creek	11.9
Leon, public boat ramp	12.1
Confluence of Eighteenmile Creek	18.6
Buffalo, public boat ramp	22.5
Confluence of Hurricane Creek	28.9
Winfield Dam [1]	31.1
Confluence of Pocatalico River	32.2
Confluence of Coal River	45.7
Saint Albans, Highway 25 bridge [1]	46.1
Charleston, Patrick Street bridge [1]	56.4
Confluence of Elk River	58.0
Charleston, 35th Street bridge [1]	60.9
Marmet Dam[1]	67.7
Chelyan, Highway 61 bridge [1]	73.6
Confluence of Cabin Creek	74.5
Confluence of Paint Creek	80.6
London Dam[1]	82.8
Deepwater railroad bridge [1]	90.0
Kanawha Falls, Highway 13 bridge [1]	94.3
Kanawha Falls	95.2
Confluence of Gauley River and New River	96.6
Gauley Bridge, railroad bridge over New River [1]	97.8
Elkem Metals Hydroelectric Power Plant tailrace on New River	98.1
Hawks Nest Dam on New River (through Hawks Nest Aqueduct)	101.2

[1] Water-sample collection location.

can be used to determine traveltimes between locations of different dye injections. For example, using figure 5, the traveltime of the trailing edge between Deepwater (collection location for the injection at Hawks Nest) and Saint Albans (collection location for the injection at Marmet Dam) is approximately 205 hours (231 hours - 26 hours = 205 hours). Similarly, using figure 5, a spill at Gauley Bridge would be estimated to take about 15 days to pass Winfield Dam, and the spill

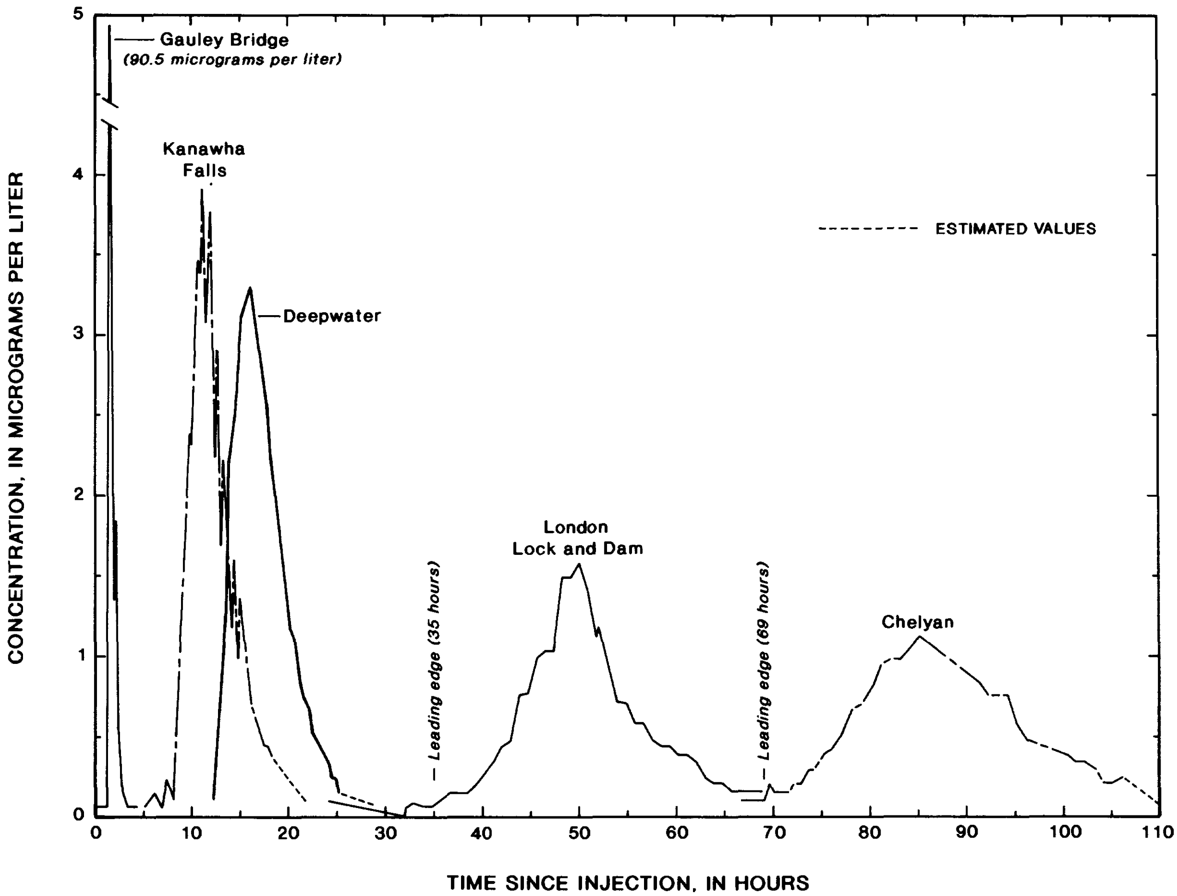

Figure 2.--Observed time-concentration curves for the dye injection at Hawks Nest Dam. (Injected at 1200 hours on June 25, 1991.)

would spend about 12 days in the Winfield pool. These cumulative traveltimes should be used as estimates only when river discharges are similar to flows of this study.

Dispersion

Time-concentration curves (figs. 2 - 4) illustrate stream dispersion. The peak concentration decreases as time since injection increases. Dispersion is also indicated by time of passage (defined as the time of trailing edge minus the time of leading edge, table 3). Time of passage increases as time since injection increases. As shown in figure 5 and by the discussion in the previous section concerning a spill at Gauley Bridge being in the Winfield pool for about 12 days, the estimated time of passage at Marmet Dam is about 2.5 days and at Winfield Dam about 5.5 days.

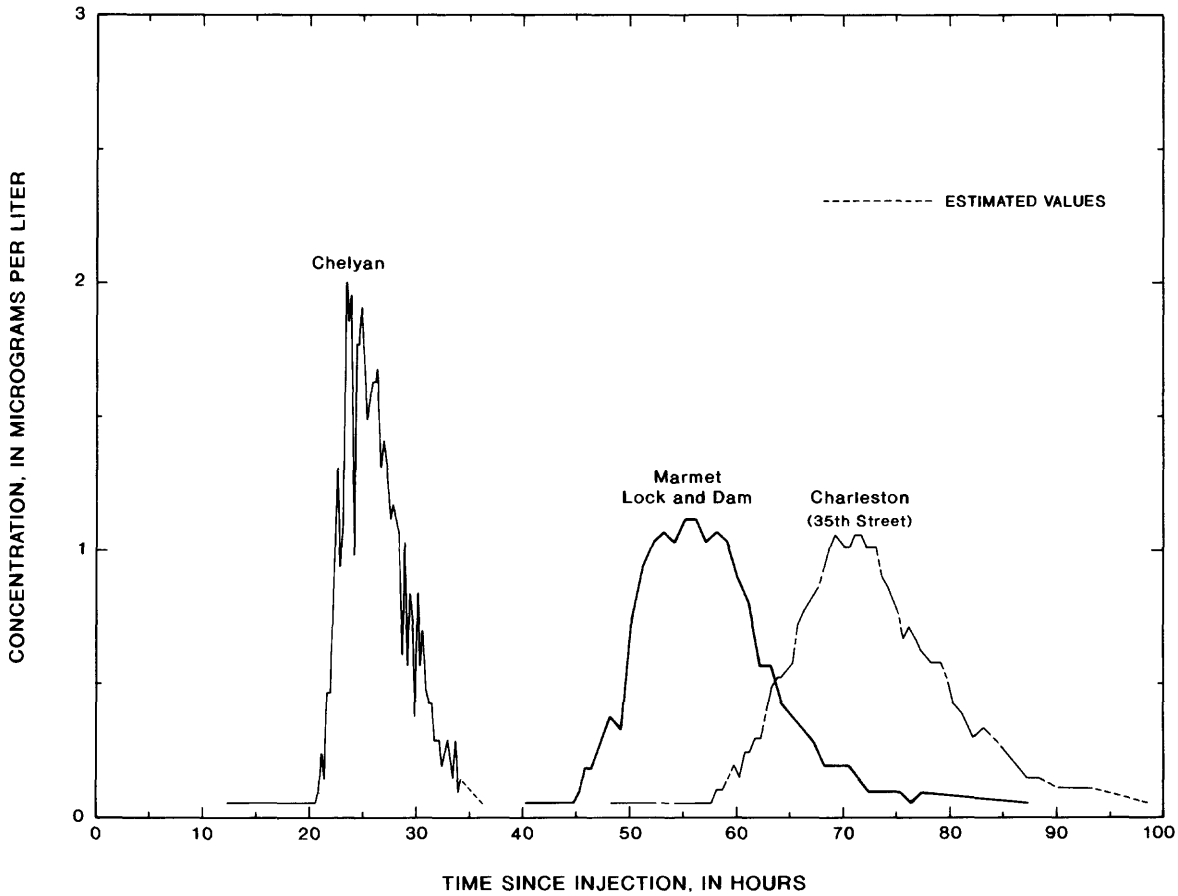

Figure 3.--Observed time-concentration curves for the dye injection at London Dam. (Injected at 1800 hours on June 24, 1991.)

Conservative-peak and unit-peak concentrations are shown in table 3. The conservative-peak concentration is the observed-peak concentration adjusted for any dye loss, and the unit-peak concentration is the conservative-peak concentration expressed as a concentration per unit weight of discharge. Differences in the unit-peak concentrations between reaches are primar--ily due to differences in longitudinal dispersion. Conservative and unit-peak concentrations can be used to develop relations to predict peak concentrations at discharges where measurements are not made. Additional dye measurements are required to develop these relations.

DISCHARGE AND WATER-SURFACE ELEVATION DATA

Discharge data describe the volume of water moving per unit time in a river system. Because of river regulation in this river system, water-

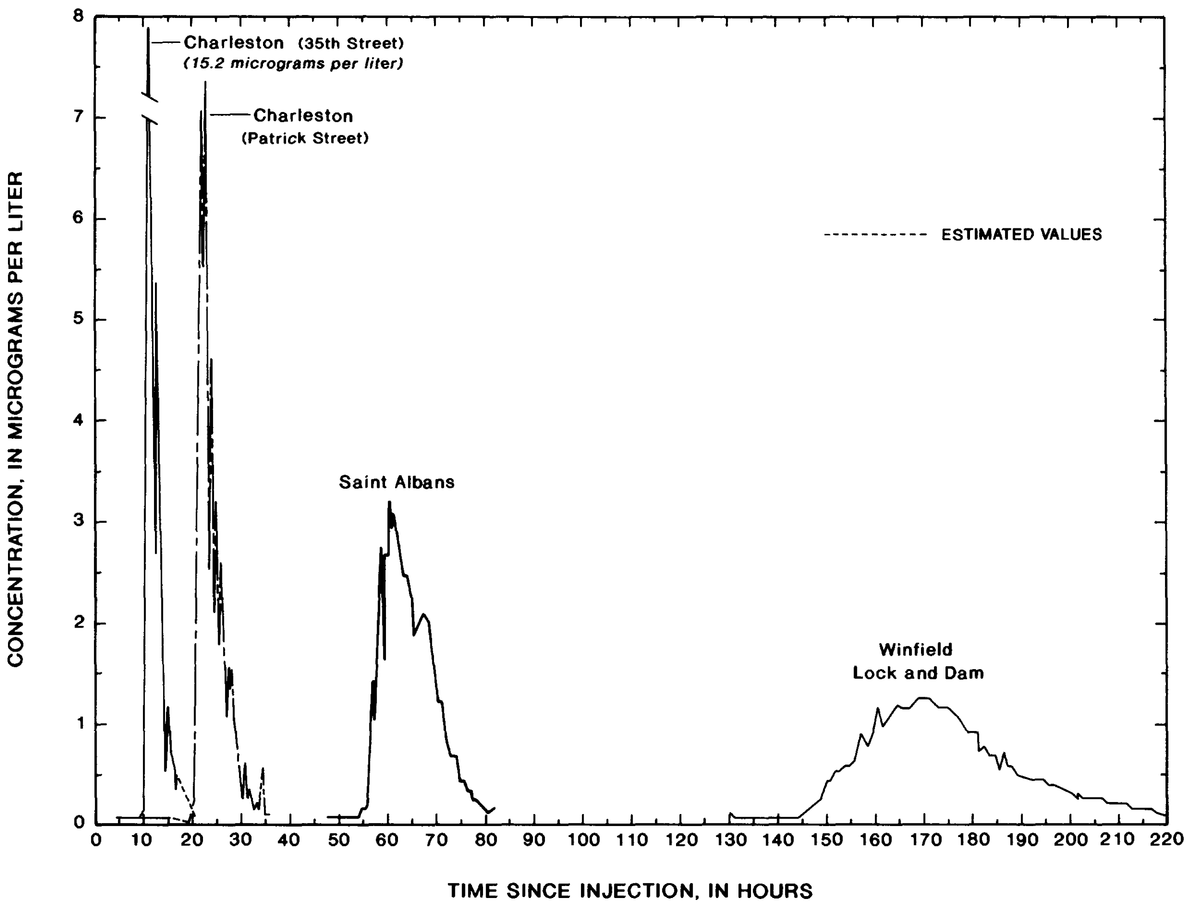

Figure 4.--Observed time-concentration curves for the dye injection at Marmet Dam. (Injected at 0700 hours on June 24, 1991.)

surface elevation data are necessary to account for changes in water storage. Changes in discharge and storage can affect traveltime and dispersion of a conservative solute in this river system.

Collection Methods

Discharge and water-surface elevation data are collected at established U.S. Geological Survey streamflow-gaging stations. Table 4 is a list of streamflow-gaging stations applicable to this study. Discharge and water-surface elevation data for the streamflow-gaging stations are measured by standard methods described by Rantz and others (1982). Daily mean discharge and water-surface elevation data collected for this study are presented in table 8 at the end of the report.

Table 2.--*Traveltime and related data for the 1991 dye study*

[Distances are measured upstream from the mouth of the Kanawha River; mi, mile; h, hour; mi/h, mile per hour; lb, pound]

Site	Site name	Distance: Upstream from mouth (mi)	Distance: Subreach length (mi)	Distance: From point of injection (mi)	Leading edge: Time since injection (h)	Leading edge: Traveltime (h)	Leading edge: Cumulative traveltime (h)	Leading edge: Velocity (mi/h)	Peak concentration: Time since injection (h)	Peak concentration: Traveltime (h)	Peak concentration: Cumulative traveltime (h)	Peak concentration: Velocity (mi/h)	Trailing edge: Time since injection (h)	Trailing edge: Traveltime (h)	Trailing edge: Cumulative traveltime (h)	Trailing edge: Velocity (mi/h)
	Injected 100 lb of 20-percent rhodamine-WT dye at 1200 hours on June 25, 1991, at Hawks Nest Dam (through Hawks Nest Aqueduct), mile 101.2															
1	Gauley Bridge (New River)	97.8		3.4	1.2		0		1.3		0		3.2		0	
			3.5			5.3		0.66		9.7		0.36		18.8		0.19
2	Kanawha Falls	94.3		6.9	6.5		5.3		11		9.7		22		18.8	
			4.3			4.5		.96		5.0		.86		7.0		.61
3	Deepwater	90.0		11.2	11		9.8		16		14.7		29		25.8	
			7.2			24		.30		34		.21		42		.17
4	London	82.8		18.4	35		33.8		50		48.7		71		67.8	
			9.2			34		.27		35		.26		39		.24
5	Chelyan	73.6		27.6	69		67.8		85		83.7		110		106.8	
	Injected 75 lb of 20-percent rhodamine-WT dye at 1800 hours on June 24, 1991, at London Dam, mile 82.8															
5	Chelyan	73.6		9.2	20.5		—		23.2		—		36		—	
			5.9			24.5		.24		31.8		.19		44		.13
6	Marmet	67.7		15.1	45		92.3		55		115.5		80		150.8	
			6.8			12.5		.54		14		.49		18		.38
7	Charleston, 35th Street	60.9		21.9	57.5		104.8		69		129.5		98		168.8	
	Injected 200 lb of 20-percent rhodamine-WT dye at 0700 hours on June 24, 1991, at Marmet Dam, mile 67.7															
7	Charleston, 35th Street	60.9		6.8	9.5		---		10.8		—		20		—	
			4.5			9.7		.46		11.4		.39		16		.28
8	Charleston, Patrick Street	56.4		11.3	19.2		114.5		22.2		140.9		36		184.8	
			10.3			34.8		.30		38.5		.27		46		.22
9	Saint Albans	46.1		21.6	54		149.3		60.7		179.4		82		230.8	
			15.0			90		.17		109.3		.14		137		.11
10	Winfield	31.1		36.6	144		239.3		170		288.7		219		367.8	

Table 3.--*Dispersion and related data for the 1991 dye study*

[Distances are measured upstream from the mouth of the Kanawha River; h, hour; Q, discharge at sampling site; T-C, time-concentration; A_c, area under time-concentration curve; L-h, liter-hour; lb, pound; µg/L, micrograms per liter; R_p, percent recovery; C_{obs}, observed-peak concentration; C_p, conservative-peak concentration; P_1, peak concentration produced from one pound of dye; C_{up}, unit peak concentration]

Site	Site name	Time of passage of dye cloud (h)	Discharge at sampling site[1] (Q)	Area under T-C curve (Ac) (µg/L-h)	Percent recovery[2] (R_p)	Observed-peak concentration in (C_{obs}) (µg/L)	Conservative-peak concentration[3] (C_p)	Peak concentration produced by 1 lb of dye[4] (P_1)	Unit-peak concentration[5] (C_{up})
	Injected 100 lb of 20-percent rhodamine-WT dye at 1200 hours on June 25, 1991, at Hawks Nest Dam (through Hawks Nest Aqueduct), mile 101.2								
1	Gauley Bridge (New River)	2.0	4,700	20.19	107	90.47	84.55	4.23	19,900
2	Kanawha Falls	15.5	4,900	16.60	91.4	3.89	4.26	.21	1,030
3	Deepwater	18.0	4,900	19.22	106	3.29	3.10	.16	784
4	London	36.0	4,300	17.65	85.3	1.57	1.84	.092	396
5	Chelyan	41.0	3,800	20.10	85.8	1.11	1.29	.065	247
	Injected 75 lb of 20-percent rhodamine-WT dye at 1800 hours on June 24, 1991, at London Dam, mile 82.8								
5	Chelyan	15.5	4,900	11.34	83.2	1.99	2.39	.16	784
6	Marmet	35.0	5,000	15.29	115	1.11	.96	.064	320
7	Charleston, 35th Street	40.5	5,000	15.42	116	1.05	.91	.061	305
	Injected 200 lb of 20-percent rhodamine-WT dye at 0700 hours on June 24, 1991, at Marmet Dam, mile 67.7								
7	Charleston, 35th Street	10.5	5,200	27.59	80.6	15.15	18.80	.47	2,440
8	Charleston, Patrick Street	16.8	5,400	27.54	83.6	7.34	8.78	.22	1,190
9	Saint Albans	28.0	5,200	34.10	99.6	3.19	3.20	.080	416
10	Winfield	75.0	4,000	39.77	89.4	1.24	1.39	.035	140

[1] Q, in cubic feet per second, where Q is the average discharge over the time of passage of the dye cloud.
[2] R_p, in percent = $(2.24762 \bullet 10\ QAc)/(W_sC_s)$, where W_s is the weight of stock solution in pounds, and C_s is the concentration of stock solution in micrograms per liter.
[3] C_p, in micrograms per liter = $100(C_{obs}/R_p)$.
[4] P_1, in micrograms per liter = C_p/W_d, where W_d is the weight of pure dye in pounds.
[5] C_{up}, in micrograms-(cubic feet per second) per liter = $Q(C_p/W_d)$ pounds.

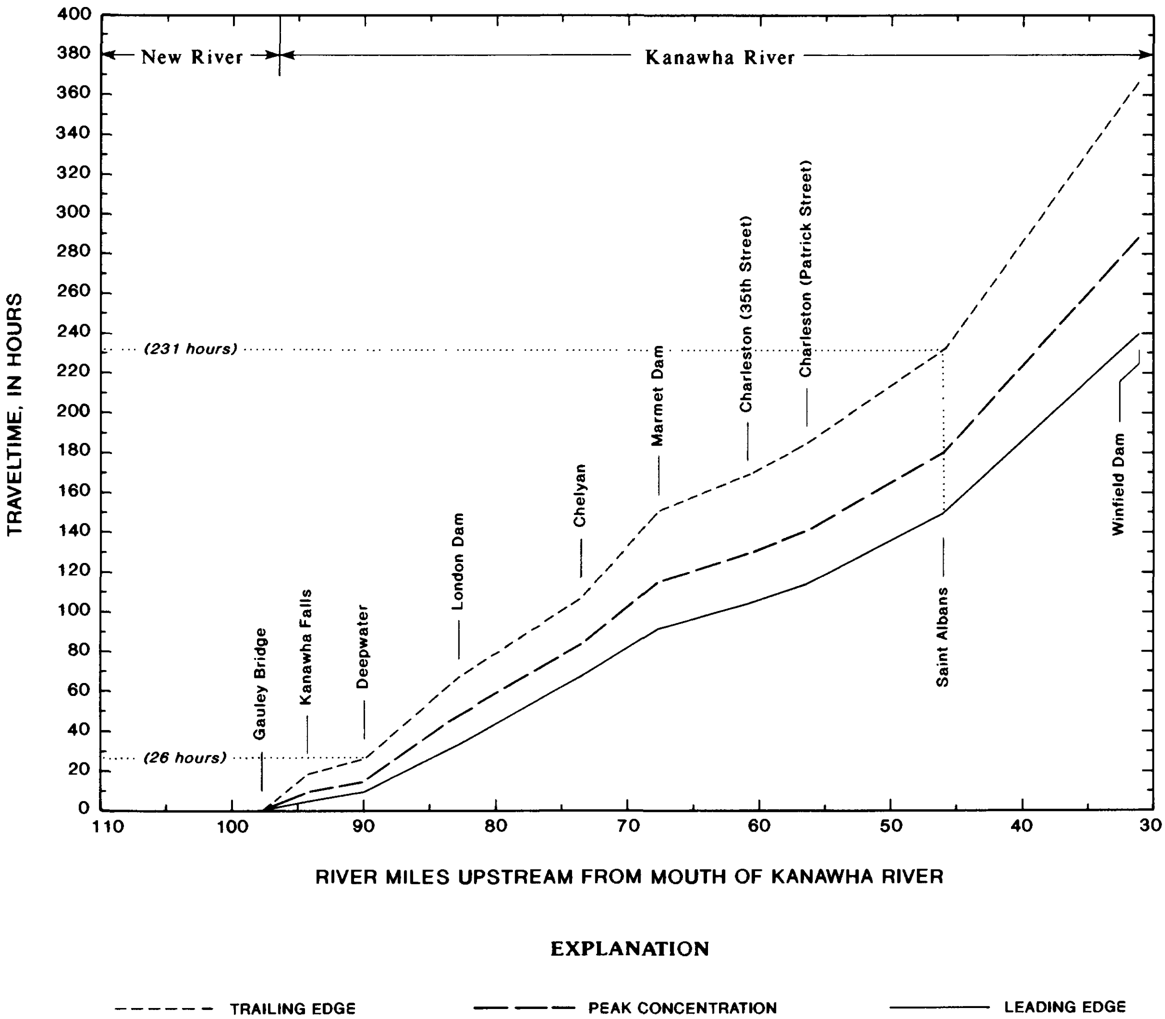

Figure 5.--Cumulative traveltimes for the 1991 dye study.

Discharge

River discharges decreased from June 24 through July 3, 1991. Discharge of the Kanawha River was measured at Kanawha Falls and Charleston (fig. 6). Daily mean discharge ranged from 5,540 ft^3/s on June 24 to 2,790 ft^3/s on July 2 at Kanawha Falls and from 5,680 ft^3/s on June 24 to 3,000 ft^3/s on July 2 at Charleston. Inflows to the Kanawha River were measured at Belva on the Gauley River, Queen Shoals on the Elk River, and Tornado on the Coal River (fig. 7). Daily mean discharge ranged from 208 ft^3/s to 132 ft^3/s at Belva, from 231 ft^3/s to 66 ft^3/s at Queen Shoals, and from 376 ft^3/s to 131 ft^3/s at Tornado.

Water-Surface Elevation

Normal water-surface elevations for the navigable section of the Kanawha River are shown in figure 8. Water-surface elevations for the study period were approximately 1 ft above normal downstream from Winfield Dam in the pool regulated by Gallipolis Dam on the Ohio River (fig. 9). Water-surface elevations were near normal for the Winfield pool (fig. 10), Marmet pool (fig. 11), and London pool (fig. 12).

Table 4.--*Location and additional information for selected streamflow-gaging stations*

[mi, mile; mi^2, square miles; ft, feet; RM, river mile; gage datum is the elevation of zero stage and is measured in feet above sea level; "Yes" indicates data are collected; "No" indicates data are not collected]

Streamflow-gaging station	Location	Gage datum	Drainage area (mi^2)	Stage data	Discharge data
03192000	Gauley River above Belva (6.3 mi above mouth)	669.00	1,317	Yes	Yes
03193000	Kanawha River at Kanawha Falls (at RM 94.3)	621.20	8,371	Yes	Yes
03193700	Kanawha River at London, upstream of dam (at RM 82.8)	600.15	8,493	Yes	No
03193701	Kanawha River at London, downstream of dam (at RM 82.8)	580.19	8,493	Yes	No
03193800	Kanawha River at Marmet, upstream of dam (at RM 67.7)	580.18	8,816	Yes	No
03193805	Kanawha River at Marmet downstream of dam (at RM 67.7)	560.27	8,816	Yes	No
03197000	Elk River at Queen Shoals (26.2 mi above mouth)	604.09	1,145	Yes	Yes
03197990	Kanawha River at Charleston, auxiliary gage (at RM 56.9)	547.00	10,419	Yes	No
03198000	Kanawha River at Charleston, base gage (at RM 54.5)	548.00	10,448	Yes	Yes
03200500	Coal River at Tornado (11.5 mi above mouth)	570.46	862	Yes	Yes
03201301	Kanawha River at Winfield, upstream of dam (at RM 31.1)	560.00	11,809	Yes	No
03201305	Kanawha River at Winfield, downstream of dam (at RM 31.1)	530.00	11,809	Yes	No
03201500	Ohio River at Point Pleasant (1,200 ft upstream from confluence of Kanawha River)	513.57	[1] 52,760	Yes	No

[1] Approximate drainage area, including that of the Kanawha River.

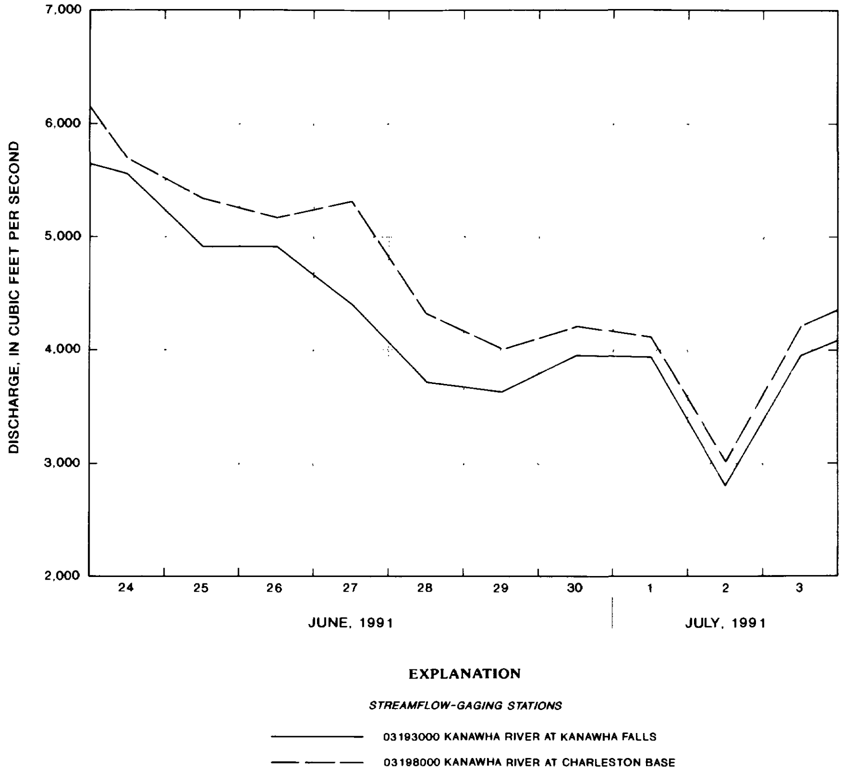

Figure 6.--Daily mean discharges for the Kanawha River at Kanawha Falls and Charleston, June 24 through July 3, 1991.

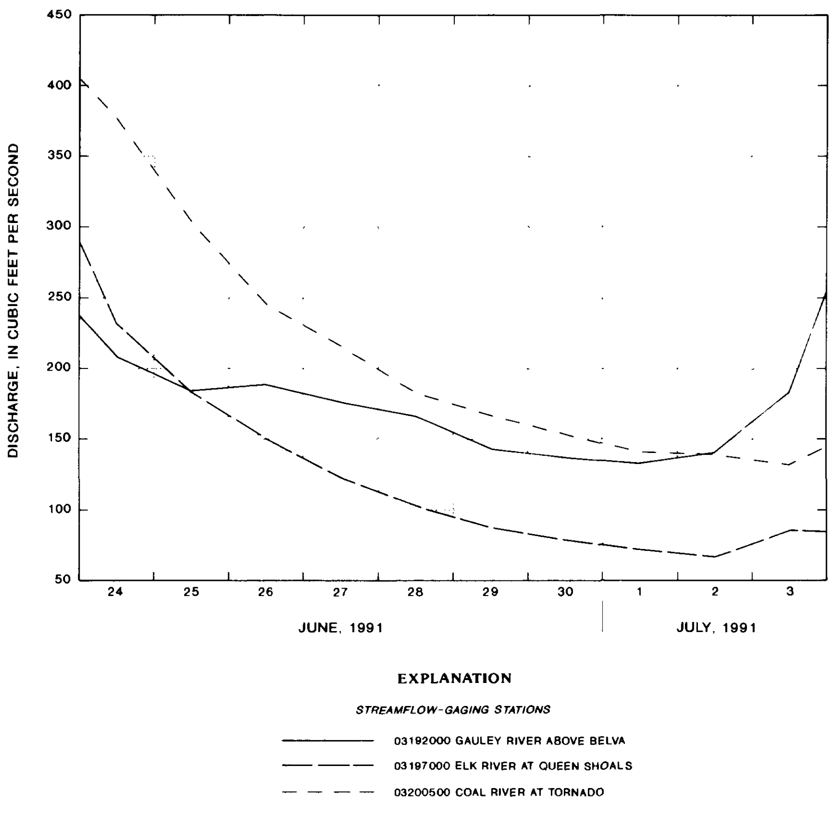

Figure 7.--Daily mean discharges for the Kanawha River from the Gauley, Elk, and Coal Rivers, June 24 through July 3, 1991.

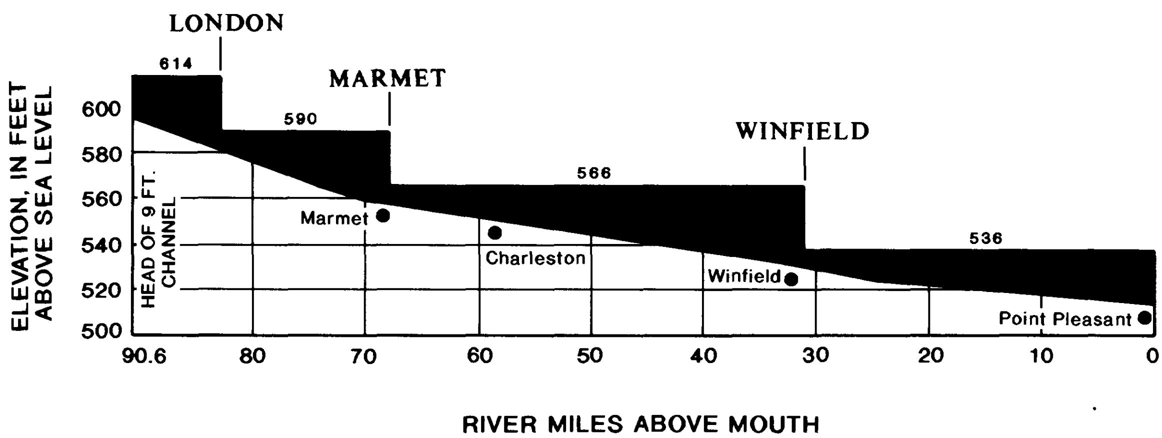

Figure 8.--Kanawha River profile, navigable section. (From Appel, 1991, p. 4)

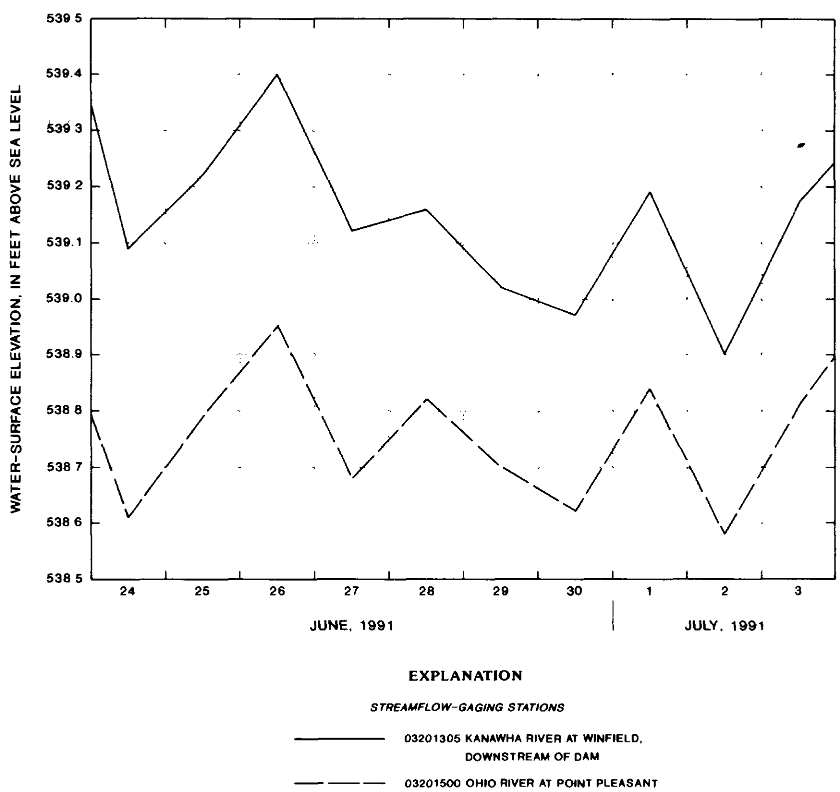

Figure 9--Daily mean water-surface elevations from June 24 through July 3, 1991, at Winfield and Point Pleasant in the Gallipolis pool.

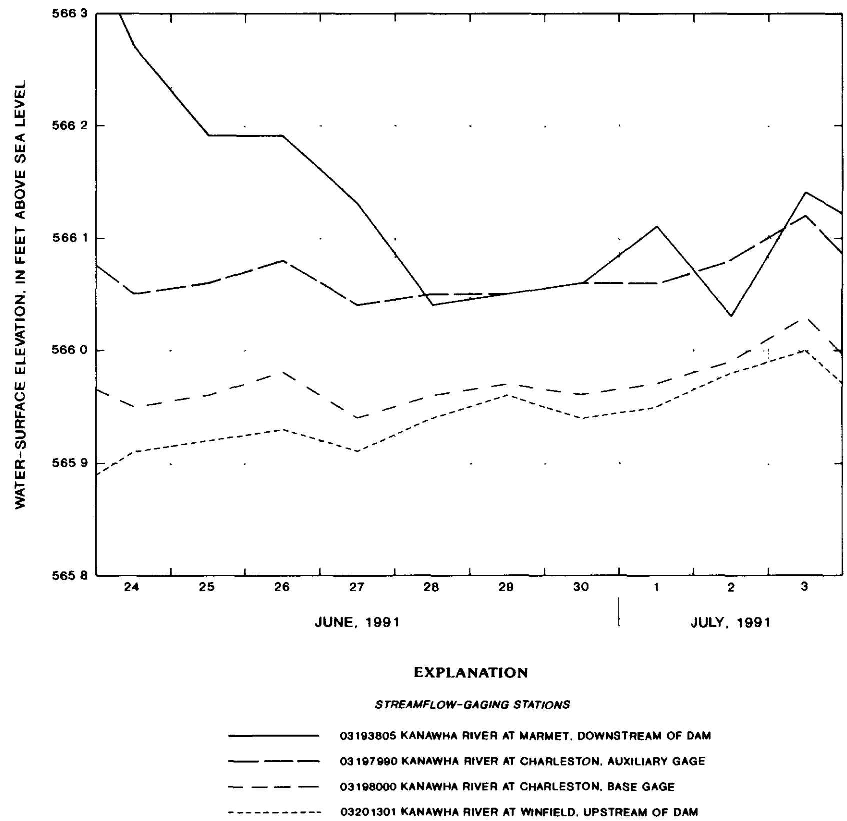

Figure 10.--Daily mean water-surface elevations from June 24 through July 3, 1991, at Winfield, Charleston, and Marmet in the Winfield pool.

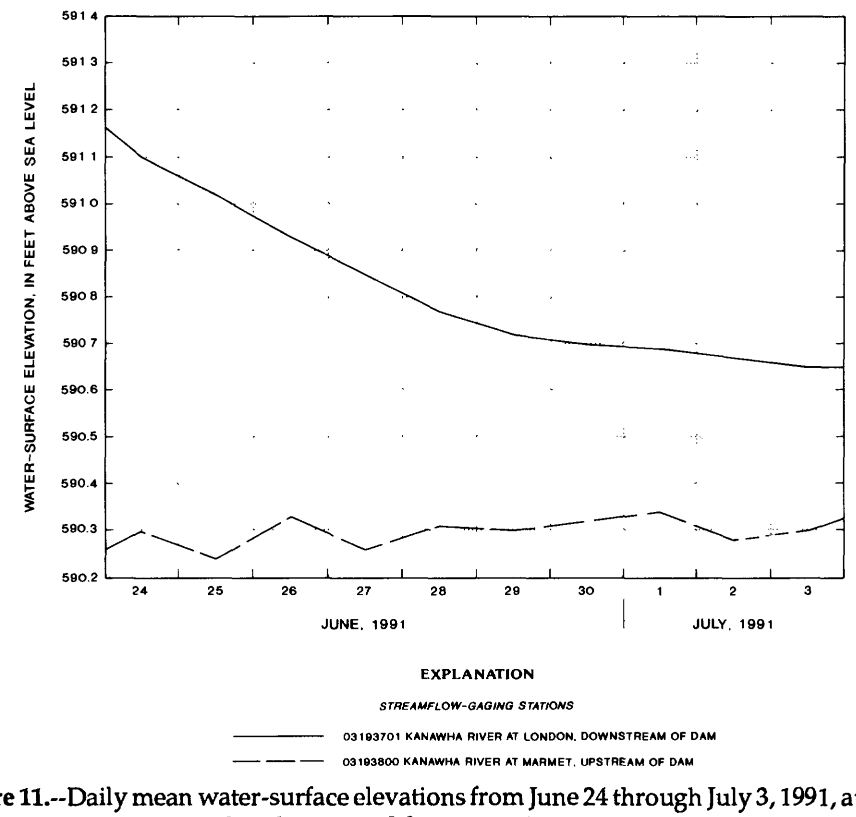

Figure 11.--Daily mean water-surface elevations from June 24 through July 3, 1991, at Marmet and London in the Marmet pool.

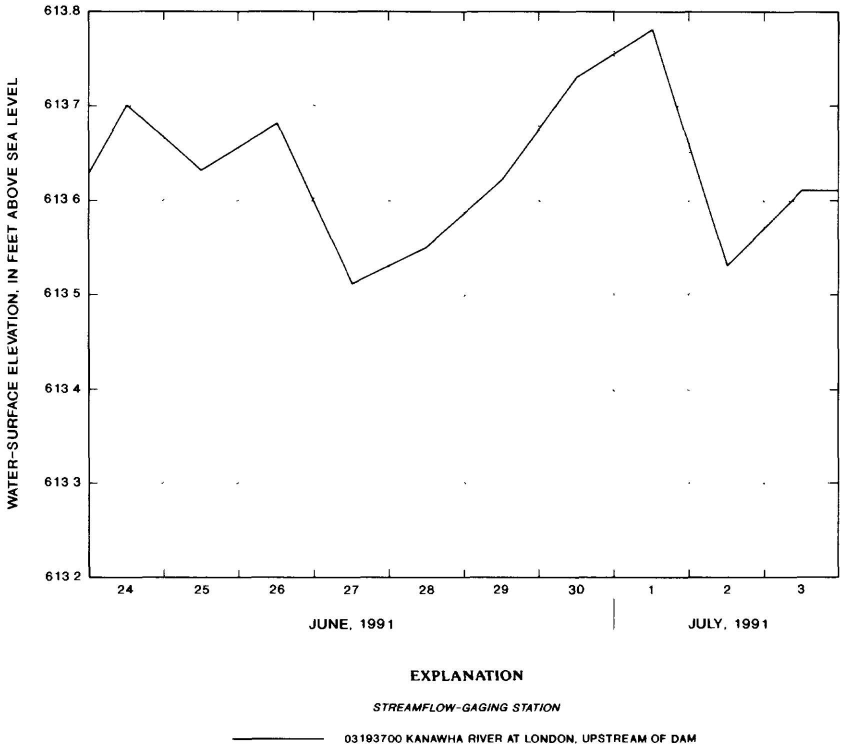

Figure 12.--Daily mean water-surface elevations from June 24 through July 3, 1991, at London in the London pool.

Between June 24 and July 3, 1991, a reduction of water storage in regulated pools occurred. This is indicated by the decline in water-surface elevations at upstream locations in the Gallipolis, Winfield, and Marmet pools, in comparison to the more stable water-surface elevations at the downstream locations in the pools (figs. 9-11).

SUMMARY

The Kanawha River originates in south-central West Virginia and flows northwest to the Ohio River. The river is used for water supply, recreation, and transportation. Water quality of the river could be affected by an accidental spill of a soluble contaminant. Knowledge of estimated traveltimes and dispersion of solutes could help river managers to mitigate effects of such a spill. Traveltime and dispersion data were collected from June 24 through July 3, 1991. This data supplements data collected in August and October 1989.

Dye was injected at Hawks Nest Aqueduct, London Dam, and Marmet Dam. Water samples were collected at various river locations and analyzed for the presence of dye. Time-concentration curves were developed from this data and cumulative traveltimes were calculated (these curves and calculations should be used for making estimates only when river discharges are similar to this study). A spill of soluble material at Gauley Bridge under similar discharge conditions is estimated to take about 15 days to pass Winfield Dam. A spill is estimated to spend about 12 days in the Winfield pool. Estimated time of passage for this hypothetical spill is about 2.5 days at Marmet Dam and about 5.5 days at Winfield Dam.

River discharge decreased from June 24 through July 3, 1991. Daily mean discharges ranged from 5,540 ft^3/s to 2,790 ft^3/s at Kanawha Falls and from 5,680 ft^3/s to 3,000 ft^3/s at Charleston.

Water-surface elevations were 1 ft above normal in the Gallipolis pool, and were near normal in the Winfield, Marmet, and London pools. Changing water-surface elevations in the regulated pools indicated a loss of water storage during the study period.

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Table 5.--*Unit times and concentrations at the indicated locations for the dye injection at Hawks Nest Dam, through Hawks Nest Aqueduct*

[Time is military time. Elapsed time is in percentage of hours since injection. Concentration is in micrograms per liter]

Gauley Bridge, railroad bridge over New River

Date	Time	Elapsed time	Concentration	Date	Time	Elapsed time	Concentration
6-25-91	1200	0.00	0.05	6-25-91	1335	1.58	10.25
	1205	.08	.05		1340	1.67	4.68
	1210	.17	.05		1345	1.75	2.45
	1220	.33	.05		1351	1.85	1.34
	1230	.50	.05		1355	1.92	1.81
	1240	.67	.05		1400	2.00	1.20
	1250	.83	.05		1410	2.17	.56
	1300	1.00	.05		1420	2.33	.42
	1305	1.08	.05		1430	2.50	.28
	1310	1.17	.05		1445	2.75	.14
	1315	1.25	15.30		1500	3.00	.09
	1320	1.33	90.47		1515	3.25	.05
	1325	1.42	70.34		1530	3.50	.05
	1330	1.50	27.71		1600	4.00	.05

Kanawha Falls, Highway 13 bridge

Date	Time	Elapsed time	Concentration	Date	Time	Elapsed time	Concentration
6-25-91	1700	5.00	0.05	6-26-91	0045	12.75	1.67
	1800	6.00	.14		0100	13.00	2.22
	1845	6.75	.05		0115	13.25	1.25
	1915	7.25	.23		0130	13.50	2.13
	2000	8.00	.09		0145	13.75	1.30
	2015	8.25	.23		0200	14.00	1.16
	2030	8.50	.46		0215	14.25	1.57
	2045	8.75	.56		0230	14.50	.97
	2100	9.00	1.48		0245	14.75	1.34
	2115	9.25	1.67		0300	15.00	1.20
	2130	9.50	2.08		0315	15.25	1.02
	2145	9.75	2.36		0330	15.50	.88
	2200	10.00	2.32		0345	15.75	.83
	2215	10.25	2.92		0400	16.00	.65
	2230	10.50	3.43		0415	16.25	.60
	2245	10.75	3.38		0430	16.50	.56
	2300	11.00	3.89		0445	16.75	.51
	2315	11.25	3.06		0500	17.00	.46
	2345	11.75	3.75		0520	17.33	.42
	2400	12.00	3.57		0540	17.67	.42
6-26-91	0015	12.25	2.22		0600	18.00	.37
	0030	12.50	2.87				

Table 5.--*Unit times and concentrations at the indicated locations for the dye injection at Hawks Nest Dam, through Hawks Nest Aqueduct*--Continued

[Time is military time. Elapsed time is in percentage of hours since injection. Concentration is in micrograms per liter]

Date	Time	Elapsed time	Concentration	Date	Time	Elapsed time	Concentration
			Deepwater, railroad bridge				
6-25-91	2400	12.00	0.09	6-26-91	0620	18.33	2.08
6-26-91	0020	12.33	.32		0640	18.67	1.90
	0040	12.67	.60		0700	19.00	1.67
	0100	13.00	.83		0720	19.33	1.53
	0120	13.33	1.16		0740	19.67	1.32
	0140	13.67	2.18		0800	20.00	1.16
	0200	14.00	2.32		0820	20.33	1.11
	0220	14.33	2.50		0840	20.67	1.02
	0240	14.67	2.87		0900	21.00	.83
	0300	15.00	3.10		0920	21.33	.74
	0320	15.33	3.15		0940	21.67	.69
	0340	15.67	3.24		1000	22.00	.65
	0400	16.00	3.29		1020	22.33	.51
	0420	16.33	3.15		1040	22.67	.46
	0440	16.67	2.96		1200	24.00	.32
	0500	17.00	2.78		1220	24.33	.23
	0520	17.33	2.64		1240	24.67	.23
	0540	17.67	2.50		1300	25.00	.14
	0600	18.00	2.22				
			London Dam				
6-26-91	1200	24.00	0.09	6-27-91	0925	45.42	0.97
	1945	31.75	.00		1019	46.32	1.02
	2000	32.00	.05		1113	47.21	1.02
	2053	32.89	.09		1206	48.10	1.48
	2147	33.78	.05		1300	49.00	1.48
	2241	34.68	.05		1353	49.89	1.57
	2335	35.58	.09		1447	50.79	1.39
6-27-91	0028	36.47	.14		1541	51.68	1.11
	0216	38.26	.14		1600	52.00	1.16
	0310	39.16	.19		1654	52.90	.88
	0457	40.95	.32		1759	53.81	.69
	0550	41.84	.42		1853	54.71	.69
	0644	42.74	.46		1937	55.62	.56
	0738	43.63	.74		2031	56.52	.56
	0832	44.53	.76		2126	57.43	.46

Table 5.--*Unit times and concentrations at the indicated locations for the dye injection at Hawks Nest Dam, through Hawks Nest Aqueduct*--Continued

[Time is military time. Elapsed time is in percentage of hours since injection. Concentration is in micrograms per liter]

Date	Time	Elapsed time	Concentration	Date	Time	Elapsed time	Concentration
			London Dam--Continued				
6-27-91	2220	58.33	0.42	6-28-91	0441	64.69	0.19
	2314	59.24	.42		0534	65.57	.14
6-28-91	0008	60.14	.37		0629	66.48	.14
	0103	61.05	.37		0723	67.38	.14
	0157	61.95	.32		1006	70.10	.14
	0252	62.86	.23		1100	71.00	.14
	0346	63.76	.19				
			Chelyan, Highway 61 bridge				
6-28-91	0630	66.50	0.09	6-28-91	1900	79.00	0.69
	0700	67.00	.09		2000	80.00	.79
	0730	67.50	.09		2100	81.00	.93
	0800	68.00	.09		2200	82.00	.97
	0830	68.50	.09		2300	83.00	.97
	0900	69.00	.09	6-29-91	0100	85.00	1.11
	0930	69.50	.19		0700	91.00	.83
	1000	70.00	.14		0800	92.00	.74
	1030	70.50	.14		0900	93.00	.74
	1100	71.00	.14		1000	94.00	.74
	1130	71.50	.14		1100	95.00	.56
	1200	72.00	.19		1200	96.00	.46
	1230	72.50	.19		1600	100.00	.37
	1300	73.00	.23		1700	101.00	.32
	1330	73.50	.28		1800	102.00	.32
	1400	74.00	.28		1900	103.00	.28
	1500	75.00	.37		2000	104.00	.19
	1600	76.00	.42		2100	105.00	.19
	1700	77.00	.51		2200	106.00	.23
	1800	78.00	.65				

Table 6.--*Unit times and concentrations at the indicated locations for the dye injection at London Dam*

[Time is military time. Elapsed time is in percentage of hours since injection. Concentration is in micrograms per liter]

Date	Time	Elapsed time	Concentration	Date	Time	Elapsed time	Concentration
			Chelyan, Highway 61 bridge				
6-25-91	0603	12.05	0.05	6-25-91	2045	26.75	1.39
	1333	19.55	.05		2100	27.00	1.39
	1345	19.75	.05		2115	27.25	1.30
	1400	20.00	.05		2130	27.50	1.11
	1415	20.25	.05		2145	27.75	1.16
	1430	20.50	.05		2200	28.00	1.11
	1445	20.75	.09		2215	28.25	1.06
	1500	21.00	.23		2230	28.50	.60
	1515	21.25	.14		2245	28.75	1.02
	1530	21.50	.46		2300	29.00	.56
	1545	21.75	.46		2315	29.25	.83
	1600	22.00	.83		2330	29.50	.74
	1615	22.25	.97		2345	29.75	.37
	1630	22.50	1.30		2400	30.00	.83
	1645	22.75	.93	6-26-91	0015	30.25	.56
	1700	23.00	1.11		0030	30.50	.69
	1715	23.25	1.99		0045	30.75	.46
	1730	23.50	1.85		0100	31.00	.42
	1745	23.75	1.94		0115	31.25	.42
	1800	24.00	.97		0130	31.50	.28
	1815	24.25	1.76		0145	31.75	.28
	1830	24.50	1.76		0200	32.00	.28
	1845	24.75	1.90		0215	32.25	.19
	1900	25.00	1.67		0230	32.50	.23
	1915	25.25	1.48		0245	32.75	.28
	1930	25.50	1.48		0300	33.00	.19
	1945	25.75	1.62		0315	33.25	.14
	2000	26.00	1.62		0330	33.50	.28
	2015	26.25	1.67		0345	33.75	.09
	2030	26.50	1.30		0400	34.00	.14
			Marmet Dam				
6-26-91	1003	40.05	0.05	6-26-91	1445	44.75	0.05
	1258	42.97	.05		1512	45.20	.09
	1325	43.42	.05		1538	45.64	.18
	1352	43.86	.05		1605	46.09	.23
	1419	44.31	.05		1632	46.53	.23

Table 6.--*Unit times and concentrations at the indicated locations for the dye injection at London Dam*--Continued

[Time is military time. Elapsed time is in percentage of hours since injection. Concentration is in micrograms per liter]

Date	Time	Elapsed time	Concentration	Date	Time	Elapsed time	Concentration
			Marmet Dam--Continued				
6-26-91	1659	46.98	0.28	6-27-91	1100	65.00	0.37
	1725	47.42	.32		1200	66.00	.32
	1800	48.00	.37		1300	67.00	.28
	1900	49.00	.32		1400	68.00	.19
	2000	50.00	.74		1415	68.25	.19
	2100	51.00	.93		1515	69.25	.19
	2200	52.00	1.02		1615	70.25	.19
	2300	53.00	1.06		1715	71.25	.14
	2400	54.00	1.02		1815	72.25	.09
6-27-91	0100	55.00	1.11		1915	73.25	.09
	0200	56.00	1.11		2015	74.25	.09
	0300	57.00	1.02		2115	75.25	.09
	0400	58.00	1.06		2215	76.25	.05
	0500	59.00	1.02		2315	77.25	.09
	0600	60.00	.88	6-28-91	0815	86.25	.05
	0700	61.00	.79		0915	87.25	.05
	0800	62.00	.56				
	0900	63.00	.56				
	1000	64.00	.42				
			Charleston, 35th Street bridge				
6-26-91	1800	48.00	0.05	6-27-91	1000	64.00	0.52
6-27-91	0200	56.00	.05		1100	65.00	.57
	0230	56.50	.05		1130	65.50	.71
	0300	57.00	.05		1200	66.00	.76
	0330	57.50	.05		1330	67.50	.86
	0400	58.00	.10		1430	68.50	1.00
	0430	58.50	.10		1500	69.00	1.05
	0500	59.00	.14		1600	70.00	1.00
	0530	59.50	.19		1630	70.50	1.00
	0600	60.00	.14		1700	71.00	1.05
	0630	60.50	.24		1730	71.50	1.05
	0700	61.00	.24		1800	72.00	1.00
	0730	61.50	.29		1830	72.50	1.00
	0800	62.00	.29		1900	73.00	1.00
	0830	62.50	.38		1930	73.50	.90
	0900	63.00	.48		2000	74.00	.86
	0930	63.50	.52		2030	74.50	.81

Table 6.--*Unit times and concentrations at the indicated locations for the dye injection at London Dam*--Continued

[Time is military time. Elapsed time is in percentage of hours since injection. Concentration is in micrograms per liter]

Date	Time	Elapsed time	Concentration	Date	Time	Elapsed time	Concentration
			Charleston, 35th Street bridge--Continued				
6-27-91	2100	75.00	0.76	6-28-91	0300	81.00	0.38
	2130	75.50	.67		0400	82.00	.29
	2200	76.00	.71		0500	83.00	.33
	2230	76.50	.67		0600	84.00	.29
	2300	77.00	.62		0700	85.00	.24
	2400	78.00	.57		0800	86.00	.19
6-28-91	0030	78.50	.57		0900	87.00	.14
	0100	79.00	.57		1000	88.00	.14
	0130	79.50	.52		1200	90.00	.10
	0200	80.00	.43		1500	93.00	.10

Table 7.--*Unit times and concentrations at the indicated locations for the dye injection at Marmet Dam*

[Time is military time. Elapsed time is in percentage of hours since injection. Concentration is in micrograms per liter]

Date	Time	Elapsed time	Concentration	Date	Time	Elapsed time	Concentration
			Charleston, 35th Street bridge				
6-24-91	1620	9.33	0.05	6-24-91	1930	12.50	4.09
	1630	9.50	.05		1940	12.67	4.62
	1640	9.67	.10		1950	12.83	2.71
	1650	9.83	.14		2000	13.00	2.76
	1700	10.00	.81		2030	13.50	1.90
	1710	10.17	3.05		2045	13.75	.71
	1720	10.33	8.26		2100	14.00	.57
	1730	10.50	7.96		2115	14.25	.52
	1740	10.67	7.96		2130	14.50	.67
	1745	10.75	12.70		2145	14.75	1.14
	1750	10.83	15.15		2200	15.00	.95
	1820	11.33	14.23		2215	15.25	.71
	1830	11.50	14.08		2230	15.50	.67
	1840	11.67	8.72		2300	16.00	.52
	1850	11.83	8.87		2315	16.25	.33
	1910	12.17	5.36		2330	16.50	.38
	1920	12.33	3.38				
			Charleston, Patrick Street bridge				
6-24-91	1100	4.00	0.05	6-25-91	0515	22.25	7.34
	2140	14.67	.05		0530	22.50	6.27
	2200	15.00	.00		0600	23.00	2.50
	2215	15.25	.05		0615	23.25	3.98
6-25-91	0200	19.00	.00		0630	23.50	4.58
	0215	19.25	.05		0645	23.75	3.70
	0230	19.50	.09		0700	24.00	2.08
	0245	19.75	.19		0715	24.25	3.19
	0300	20.00	.28		0730	24.50	2.55
	0315	20.25	1.48		0745	24.75	2.59
	0330	20.50	2.36		0800	25.00	1.76
	0345	20.75	3.52		0815	25.25	2.55
	0400	21.00	4.63		0830	25.50	2.32
	0415	21.25	6.27		0845	25.75	1.99
	0430	21.50	7.04		0900	26.00	1.81
	0445	21.75	5.51		0915	26.25	1.76
	0500	22.00	5.51		0930	26.50	1.85

Table 7.--*Unit times and concentrations at the indicated locations for the dye injection at Marmet Dam*--Continued

[Time is military time. Elapsed time is in percentage of hours since injection. Concentration is in micrograms per liter]

Date	Time	Elapsed time	Concentration	Date	Time	Elapsed time	Concentration
			Charleston, Patrick Street bridge--Continued				
6-25-91	0945	26.75	1.06	6-25-91	1355	30.92	0.37
	1005	27.08	1.53		1415	31.25	.23
	1028	27.93	1.25		1435	31.58	.32
	1050	27.83	1.53		1515	32.25	.14
	1110	28.17	1.02		1600	33.00	.19
	1130	28.50	.93		1620	33.33	.14
	1150	28.83	.83		1640	33.67	.23
	1210	29.17	.65		1700	34.00	.14
	1230	29.50	.56		1720	34.33	.56
	1250	29.83	.23		1740	34.67	.09
	1314	30.23	.37		1800	35.00	.09
	1330	30.50	.60				
			Saint Albans, Highway 25 bridge				
6-26-91	0620	47.33	0.05	6-26-91	1920	60.33	2.92
	1200	53.00	.05		1940	60.67	3.06
	1220	53.33	.05		2000	61.00	3.01
	1240	53.67	.05		2020	61.33	2.96
	1300	54.00	.09		2040	61.67	2.82
	1320	54.33	.14		2100	62.00	2.69
	1340	54.67	.14		2120	62.33	2.59
	1400	55.00	.14		2140	62.67	2.50
	1430	55.50	.19		2200	63.00	2.45
	1440	55.67	.37		2220	63.33	2.45
	1500	56.00	.46		2300	64.00	2.32
	1520	56.33	.97		2330	64.50	2.22
	1540	56.67	1.39		2400	65.00	1.85
	1600	57.00	1.02	6-27-91	0200	67.00	2.08
	1620	57.33	1.39		0300	68.00	1.99
	1640	57.67	1.81		0500	70.00	1.20
	1700	58.00	2.36		0520	70.50	1.20
	1720	58.33	2.59		0630	71.50	.83
	1740	58.67	2.73		0700	72.00	.74
	1800	59.00	1.62		0730	72.50	.65
	1820	59.33	2.64		0800	73.00	.65
	1840	59.67	2.64		0830	73.50	.65
	1900	60.00	3.19		0900	74.00	.51

Table 7.--*Unit times and concentrations at the indicated locations for the dye injection at Marmet Dam*--Continued

[Time is military time. Elapsed time is in percentage of hours since injection. Concentration is in micrograms per liter]

Date	Time	Elapsed time	Concentration	Date	Time	Elapsed time	Concentration
			Saint Albans, Highway 25 bridge--Continued				
6-27-91	0930	74.50	0.42	6-27-91	1200	77.00	0.23
	1000	75.00	.42		1230	77.50	.23
	1030	75.50	.37		1510	80.17	.09
	1100	76.00	.32		1625	81.42	.14
	1130	76.50	.32				
			Winfield Dam				
6-29-91	1700	130.00	0.10	6-30-91	2316	160.26	1.14
	1800	131.00	.05	7-1-91	0016	161.26	.95
	1900	132.00	.05		0216	163.26	1.09
	2000	133.00	.05		0316	164.26	1.19
	2100	134.00	.05		0416	165.26	1.14
	2200	135.00	.05		0516	166.27	1.14
	2259	135.99	.05		0616	167.27	1.19
	2359	136.99	.05		0716	168.27	1.24
6-30-91	0059	137.99	.05		0816	169.27	1.24
	0159	138.99	.05		0916	170.27	1.24
	0259	139.99	.05		0930	170.50	1.24
	0359	140.99	.05		1031	171.51	1.19
	0459	141.99	.05		1131	172.52	1.14
	0559	142.99	.05		1232	173.53	1.14
	0659	143.99	.05		1332	174.54	1.14
	0759	144.98	.10		1534	176.56	1.05
	0859	145.98	.14		1735	178.58	.90
	0959	146.98	.19		1936	180.60	.90
	1059	147.98	.19		2000	181.00	.71
	1159	148.98	.29		2101	182.01	.76
	1259	149.98	.43		2201	183.01	.67
	1315	150.25	.43		2301	184.02	.67
	1415	151.25	.52	7-2-91	0001	185.02	.52
	1515	152.25	.52		0102	186.03	.71
	1615	153.25	.57		0202	187.04	.57
	1715	154.25	.57		0302	188.04	.57
	1816	155.26	.62		0403	189.05	.48
	1916	156.26	.81		0704	192.07	.43
	2016	157.26	.86		0804	193.07	.43
	2116	158.26	.76		0905	194.08	.43
	2216	159.26	.90		1005	195.08	.38

Table 7.--*Unit times and concentrations at the indicated locations for the dye injection at Marmet Dam*--Continued

[Time is military time. Elapsed time is in percentage of hours since injection. Concentration is in micrograms per liter]

Date	Time	Elapsed time	Concentration	Date	Time	Elapsed time	Concentration
			Winfield Dam--Continued				
7-2-91	1105	196.09	0.38	7-2-91	2317	208.28	0.19
	1507	200.11	.29	7-3-91	0017	209.28	.19
	1607	201.12	.24		0117	210.29	.19
	1615	201.25	.29		0217	211.29	.19
	1715	202.25	.24		0318	212.30	.14
	1816	203.26	.24		0418	213.30	.14
	1916	204.26	.24		0619	215.31	.14
	2016	205.27	.24		0719	216.31	.14
	2116	206.27	.24		0819	217.32	.10
	2217	207.28	.19		1120	220.33	.05

Table 8.--*Daily mean discharge and water-surface elevation at the indicated U.S. Geological Survey streamflow-gaging stations from June 20 through July 4, 1991 (discharge and stage are not available for all locations)*

[Discharge is in cubic feet per second. Elevation is for water surface in feet above sea level]

Date	Discharge	Elevation	Date	Discharge	Elevation
		03192000 Gauley River above Belva			
6-20-91	349	670.62	6-28-91	165	670.17
6-21-91	289	670.49	6-29-91	142	670.11
6-22-91	297	670.50	6-30-91	136	670.09
6-23-91	266	670.44	7-1-91	132	670.09
6-24-91	208	670.29	7-2-91	140	670.10
6-25-91	183	670.22	7-3-91	183	670.22
6-26-91	188	670.24	7-4-91	328	670.52
6-27-91	175	670.20			
		03193000 Kanawha River at Kanawha Falls			
6-20-91	6,860	625.47	6-28-91	3,700	624.31
6-21-91	7,720	625.76	6-29-91	3,610	624.27
6-22-91	7,220	625.59	6-30-91	3,940	624.41
6-23-91	5,730	625.08	7-1-91	3,920	624.40
6-24-91	5,540	625.01	7-2-91	2,790	623.88
6-25-91	4,900	624.79	7-3-91	3,940	624.39
6-26-91	4,900	624.78	7-4-91	4,210	624.51
6-27-91	4,390	624.59			
		03193700 Kanawha River at London, upstream of dam			
6-20-91		613.52	6-28-91		613.55
6-21-91		613.72	6-29-91		613.62
6-22-91		613.58	6-30-91		613.73
6-23-91		613.56	7-1-91		613.78
6-24-91		613.70	7-2-91		613.53
6-25-91		613.63	7-3-91		613.61
6-26-91		613.68	7-4-91		613.61
6-27-91		613.51			
		03193701 Kanawha River at London, downstream of dam			
6-20-91		591.15	6-28-91		590.77
6-21-91		591.18	6-29-91		590.72
6-22-91		591.27	6-30-91		590.70
6-23-91		591.23	7-1-91		590.69
6-24-91		591.10	7-2-91		590.67
6-25-91		591.02	7-3-91		590.65
6-26-91		590.93	7-4-91		590.65
6-27-91		590.85			

Table 8.--*Daily mean discharge and water-surface elevation at the indicated U.S. Geological Survey streamflow-gaging stations from June 20 through July 4, 1991 (discharge and stage are not available for all locations)*--Continued

[Discharge is in cubic feet per second. Elevation is for water surface in feet above sea level]

Date	Discharge	Elevation	Date	Discharge	Elevation
03193800 Kanawha River at Marmet, upstream of dam					
6-20-91		590.26	6-28-91		590.31
6-21-91		590.27	6-29-91		590.30
6-22-91		590.26	6-30-91		590.32
6-23-91		590.22	7-1-91		590.34
6-24-91		590.30	7-2-91		590.28
6-25-91		590.24	7-3-91		590.30
6-26-91		590.33	7-4-91		590.35
6-27-91		590.26			
03193805 Kanawha River at Marmet, downstream of dam					
6-20-91		567.06	6-28-91		566.04
6-21-91		566.94	6-29-91		566.05
6-22-91		566.92	6-30-91		566.06
6-23-91		566.42	7-1-91		566.11
6-24-91		566.27	7-2-91		566.03
6-25-91		566.19	7-3-91		566.14
6-26-91		566.19	7-4-91		566.10
6-27-91		566.13			
03197000 Elk River at Queen Shoals					
6-20-91	176	608.01	6-28-91	102	607.80
6-21-91	188	608.05	6-29-91	87	607.75
6-22-91	281	608.25	6-30-91	78	607.71
6-23-91	348	608.38	7-1-91	71	607.69
6-24-91	231	608.15	7-2-91	66	607.67
6-25-91	182	608.03	7-3-91	85	607.74
6-26-91	149	607.95	7-4-91	82	607.73
6-27-91	122	607.86			
03197990 Kanawha River at Charleston, auxiliary gage					
6-20-91		566.33	6-28-91		566.05
6-21-91		566.18	6-29-91		566.05
6-22-91		566.17	6-30-91		566.06
6-23-91		566.10	7-1-91		566.06
6-24-91		566.05	7-2-91		566.08
6-25-91		566.06	7-3-91		566.12
6-26-91		566.08	7-4-91		566.05
6-27-91		566.04			

Table 8.--*Daily mean discharge and water-surface elevation at the indicated U.S. Geological Survey streamflow-gaging stations from June 20 through July 4, 1991 (discharge and stage are not available for all locations)*--Continued

[Discharge is in cubic feet per second. Elevation is for water surface in feet above sea level]

Date	Discharge	Elevation	Date	Discharge	Elevation
		03198000 Kanawha River at Charleston, base gage			
6-20-91	7,590	566.20	6-28-91	4,300	565.96
6-21-91	8,270	566.04	6-29-91	3,990	565.97
6-22-91	8,100	566.03	6-30-91	4,200	565.96
6-23-91	6,610	565.98	7-1-91	4,100	565.97
6-24-91	5,680	565.95	7-2-91	3,000	565.99
6-25-91	5,320	565.96	7-3-91	4,200	566.03
6-26-91	5,150	565.98	7-4-91	4,500	565.96
6-27-91	5,300	565.94			
		03200500 Coal River at Tornado			
6-20-91	677	581.17	6-28-91	182	580.72
6-21-91	636	581.15	6-29-91	166	580.70
6-22-91	429	580.98	6-30-91	152	580.68
6-23-91	433	580.99	7-1-91	140	580.66
6-24-91	376	580.93	7-2-91	138	580.65
6-25-91	303	580.86	7-3-91	131	580.64
6-26-91	245	580.79	7-4-91	158	580.68
6-27-91	215	580.76			
		03201301 Kanawha River at Winfield, upstream of dam			
6-20-91		566.08	6-28-91		565.94
6-21-91		565.90	6-29-91		565.96
6-22-91		565.89	6-30-91		565.94
6-23-91		565.87	7-1-91		565.95
6-24-91		565.91	7-2-91		565.98
6-25-91		565.92	7-3-91		566.00
6-26-91		565.93	7-4-91		565.94
6-27-91		565.91			
		03201305 Kanawha River at Winfield, downstream of dam			
6-20-91		539.96	6-28-91		539.16
6-21-91		539.60	6-29-91		539.02
6-22-91		539.55	6-30-91		538.97
6-23-91		539.60	7-1-91		539.19
6-24-91		539.09	7-2-91		538.90
6-25-91		539.22	7-3-91		539.17
6-26-91		539.40	7-4-91		539.32
6-27-91		539.12			

Table 8.--*Daily mean discharge and water-surface elevation at the indicated U.S. Geological Survey streamflow-gaging stations from June 20 through July 4, 1991 (discharge and stage are not available for all locations)*--Continued

[Discharge is in cubic feet per second. Elevation is for water surface in feet above sea level]

Date	Discharge	Elevation	Date	Discharge	Elevation
03201500 Ohio River at Point Pleasant					
6-20-91		538.88	6-28-91		538.82
6-21-91		538.62	6-29-91		538.70
6-22-91		538.63	6-30-91		538.62
6-23-91		538.98	7-1-91		538.84
6-24-91		538.61	7-2-91		538.58
6-25-91		538.79	7-3-91		538.81
6-26-91		538.95	7-4-91		538.99
6-27-91		538.68			