Traveltime Data for Truckee River Between Tahoe City, California, and Marble Bluff Dam Near Nixon, Nevada, 1999

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U.S. GEOLOGICAL SURVEY

Open-File Report 00–363

Carson City, Nevada
2000

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CONVERSION FACTORS, ABBREVIATED WATER-QUALITY UNITS, AND VERTICAL DATUM

Multiply	By	To obtain
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
pound (lb)	0.4536	kilogram
gallon (gal)	3.785	liter
cubic foot (ft^3)	0.02832	cubic meter
foot per mile (ft/mi)	0.1894	meter per kilometer
foot per second (ft/s)	0.3048	meter per second
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
mile per hour (mi/h)	1.609	kilometer per hour
ounce (oz)	29.57	milliliter

Abbreviated water-quality units used in this report:

g/L, gram per liter
µg/L, microgram per liter

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929, formerly called "Sea-Level Datum of 1929"), which is derived from a general adjustment of the first-order leveling networks of the United States and Canada.

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Abstract

Traveltime measurements were made during 1999 along the Truckee River between Tahoe City, Calif., and Marble Bluff Dam near Nixon, Nev. Fluorescent rhodamine WT dye was injected at various locations along the river for streamflows ranging from 173 to 2,780 cubic feet per second.

The resulting data, presented in tabular and graphic form may be useful to water-quality modelers or water-resources managers concerned with predicting the movement of soluble contaminants accidentally spilled into the Truckee River. The data provided in this report also could be used to determine the dispersion-related characteristics (duration and magnitude of pollutant concentrations) that may be expected in the Truckee River.

INTRODUCTION

The use of dyes and tracing techniques provides a means of measuring the traveltime and dispersion characteristics of streams. Traveltime may be defined as the time it takes for water or soluble constituents introduced into a river to move downstream from one point to another. Introduced constituents also tend to disperse as they move downstream, causing peak concentrations to decrease and the length of the solute plume to increase. Dye tracing involves the instantaneous injection of a nontoxic, fluorescent dye at a location along the stream and sampling of the resulting dye plume at locations downstream (Buchanan, 1964; Wilson, 1968). The dye mixes with the water and moves in the same manner as the water. Traveltime is measured as the time required for movement of the centroid or center of mass of the dye plume between sampling sites. Dispersion is characterized by the time of passage of the solute plume and attenuation of the peak concentration as the plume moves downstream. Dye studies typically are made over a range of streamflows that are indexed to flows at selected stream-gaging stations.

Information on traveltime of solutes may be required for water-quality modeling or waste-transport studies and also provides an objective means for determining an appropriate course of action in response to the spilling of a soluble toxic substance. For the former purpose, the model results are usually no better quantitatively than the traveltime data used in their development because simulation of biochemical processes in water-quality models involves the calculation of time-dependent reactions. Although mean streamflow velocity may be computed from streamflow measurements made at gaging stations, such point data may not adequately characterize an entire stream reach. Extrapolation of such point data may be subject to large errors. For the latter purpose, officials responsible for public safety (including water-supply managers and regulators) and others interested in transient water-quality problems need to be able to predict passage and arrival times or peak concentration of a noxious substance released or spilled upstream. Accurate traveltime information is needed to provide a reasonable basis for deciding whether, when, and how long to suspend operations of public water-supply intakes or how best to handle any perceived threat to the river environment.

Purpose and Scope

This report describes the techniques and presents the results (in tabular and graphical form) of eight dye-tracing studies made during two flow regimes on the Truckee River between Tahoe City, Calif., and Marble Bluff Dam near Nixon, Nev. (approximately 3 mi upstream from Pyramid Lake) during 1999. Three of the eight studies were made during high flow (greater than 2,000 ft^3/s), and five during medium flow (173 to 627 ft^3/s). The high-flow studies were done during April and May, and the medium-flow studies during August and September.

Previous Dye-Tracing Investigations in Study Area

La Camera and others (1985) published, in tabular form, the physical, chemical, and biological data collected as part of the Truckee–Carson river-quality assessment (Nowlin and others, 1980) in support of water-quality modeling and investigations of trout-spawning habitats in the Truckee River system. La Camera and others (1985) included the results from 13 dye-tracer studies during the period 1979–80 for a wide range of flows in three reaches along the Truckee River—from Truckee, Calif., to Vista, Nev.; Vista to Derby Diversion Dam (hereafter, "Derby Dam") near Wadsworth, Nev.; and Derby Dam to Marble Bluff Dam near Nixon, Nev.

Brown and others (1986) analyzed the data published by La Camera and others (1985) and provided an overview of the hydrologic system of the Truckee River and Carson River Basins; presented data and computed relations in graphical, tabular, and map form; and interpreted the raw and computed data. The computed relations then were used in equations to relate velocities to flows in 43 reaches of the Truckee River from Sparks to Pyramid Lake for water-quality modeling (Nowlin, 1987). The velocity–flow relations developed by Nowlin (1987) also were used in more recent water-quality models of the Truckee River (Caupp and others, 1997).

Bohman (2000) did four traveltime studies during low-flow conditions (12 to 161 ft^3/s) on the Truckee River during November and December 1993. The four river reaches studied by Bohman (2000) were from the confluence of Steamboat Creek and the Truckee River near Sparks, Nev., to Derby Dam near Wadsworth, Nev.; from Derby Dam near Wadsworth, Nev., to Wadsworth, Nev.; from Wadsworth, Nev., to Dead Ox Wash near Nixon, Nev.; and from Dead Ox Wash near Nixon, Nev., to Marble Bluff Dam near Nixon, Nev. He tabulated and combined the 1993 data with earlier data from La Camera and others (1985) and presented graphical relations between traveltime and distance and between traveltime and flow.

DESCRIPTION OF STUDY AREA

A detailed description of the physical and hydrologic characteristics of the Truckee River was given by Van Denburgh and others (1973), Brown and others (1986), and the Jones and others (1991). The following paragraphs briefly describe the physical setting of the Truckee River. A general location map of the study area, including the relevant streamflow-gaging stations and dye-study sites, is shown in figure 1.

The Truckee River watershed is a topographically enclosed basin on the eastern slope of the Sierra Nevada along the California–Nevada border. In the part of the basin that surrounds Lake Tahoe, headwater altitudes exceed 10,000 ft above sea level. The lowest part of the basin is at the river's terminus, Pyramid Lake, where the altitude is approximately 3,795 ft above sea level. The total drainage area of the basin is 3,120 mi^2, but only 1,940 mi^2 contributes streamflow to the 116-mi-long stretch of the Truckee River above Marble Bluff Dam (about 3 mi upstream from the mouth at Pyramid Lake).

From the outlet of Lake Tahoe, the Truckee River flows generally north about 15 mi to Truckee, Calif., then northeasterly for about 28 mi across the State line to Verdi, Nev. Downstream from Verdi, the river flows to the east about 21 mi to Vista, Nev. Several major tributaries, all of which are controlled by reservoirs, join the Truckee River downstream from Tahoe City, they include Donner Creek, Martis Creek, Prosser Creek and the Little Truckee River. Just downstream from the mouth of the Little Truckee River, the Truckee River flows through a deeply incised canyon to the California–Nevada border. About 8 mi east of the border, the river passes through an alluvial valley bounded

EXPLANATION

- **Hydrographic-area boundary**
- △ 22 **Dye-injection or sampling site**—Number is site number (table 1)

1	Tahoe City
2	Squaw Creek
3	Near Truckee
4	State Highway 267
5	Old U.S. 40 bridge below Truckee
6	Boca Bridge
7	Farad
8	Verdi
9	Mogul
10	West McCarran
11	Reno
12	Steamboat Creek
13	Vista
14	Patrick
15	Near Tracy
16	Below Tracy
17	Below Derby Dam
18	Wadsworth
19	Dead Ox Wash
20	Near Nixon
21	Nixon
22	Marble Bluff Dam

- ▲ 20 **U.S. Geological Survey streamflow-gaging station**—Number is identification number used by the Survey (table 1)

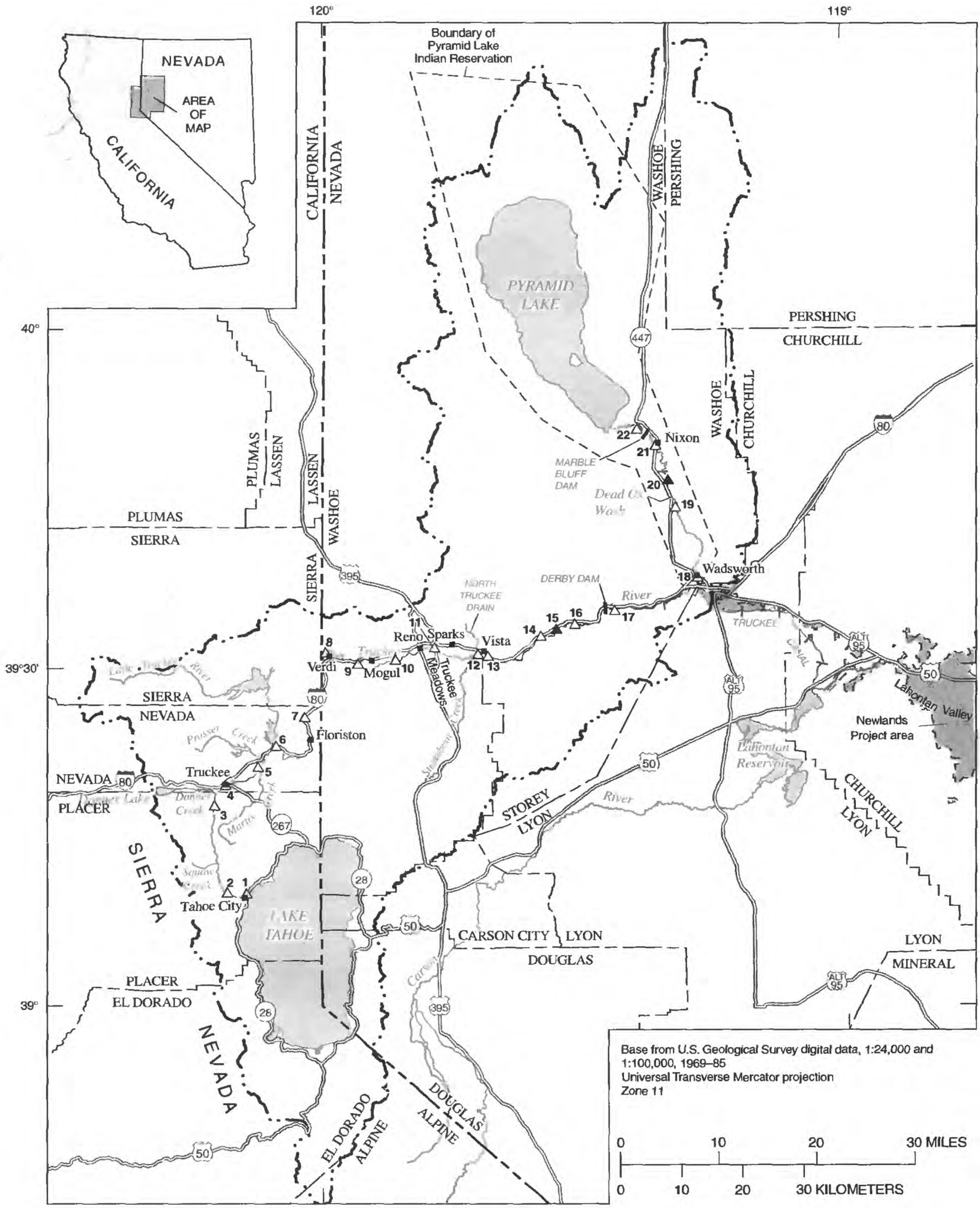

Figure 1. General location of Truckee River gaging stations and injection or sampling sites used in traveltime studies. Old U.S. Highway 40 (Glenshire Road in parts of California or State Route 427 in parts of Nevada) is not shown on map; at map scale, it roughly parallels Interstate 80. See table 1 for full site names and other alternate route names.

by mountain ranges. This area, known as the Truckee Meadows, includes the rapidly growing cities of Reno and Sparks. Although the current economy of the area is dominated by gaming and tourism, Truckee Meadows still contains irrigated agricultural lands. Both municipal and agricultural water needs are satisfied by diversions at 10 locations along the river within and upstream from the Truckee Meadows. Two hydroelectric plants are located in the western part of the Truckee Meadows; both these plants are run-of-river and divert part of the streamflow from the Truckee River near Verdi. Irrigation return flows from diversions originating on the north side of the river between Verdi and Reno and some natural flow enter the Truckee River via the North Truckee Drain near Vista, just east of Sparks. Irrigation return flows from diversions originating on the south side of the river between Verdi and Sparks, treated municipal-sewage effluent, and additional natural flows enter the river from Steamboat Creek, also near Sparks. The Truckee Meadows Water Reclamation Facility (formerly called the Reno–Sparks sewage-treatment plant) is near the mouth of Steamboat Creek.

Downstream from the Truckee Meadows, the river parallels Interstate 80 eastward for about 29 mi through arid canyon terrain to Wadsworth, Nev. At Wadsworth, the river turns north and continues for about 23 mi through the Pyramid Lake Indian Reservation to Marble Bluff Dam downstream from Nixon, Nev. Tributaries below Vista, Nev., are ephemeral; large flows are mostly in response to heavy precipitation, usually as summer thunderstorms. Downstream from Wadsworth, the channel is unstable in many areas and therefore is subject to lateral shifting within the flood plain during major floods. Population is sparse, limited to the communities of Wadsworth and Nixon and a few private ranches. The irrigation needs of small ranches bordering the lower Truckee River below Vista are served by 11 diversions. The largest diversion in this reach is the Truckee Canal. At Derby Dam (about 19 mi downstream from Vista), the canal diverts water from the river southeastward into Lahontan Reservoir in the Carson River Basin. The approximately 31-mi-long canal was constructed by the Bureau of Reclamation (U.S. Department of the Interior) as part of the Newlands Project, the Nation's first project completed under the authority of the Reclamation Act of 1902 (Jones and others, 1991, p. 23).

River gradients vary between the lower basin and the steeper mountain-block area of the upper basin. The gradient of the river is fairly steep above Reno, averaging about 35 ft/mi. Within the 8-mi reach of the river between Reno and Vista, the gradient is relatively flat (about 1.6 ft/mi). From Vista to Marble Bluff Dam, the Truckee River channel slope averages less than 10 ft/mi. The numerous diversion structures have important localized effects on the channel slope. Resultant decreases in flow velocities and increases in flow depths upstream from diversion structures undoubtedly influence both traveltime and dispersion characteristics of the river (Nowlin, 1987).

DATA COLLECTION, QUALITY ASSURANCE, AND RESULTS

This report presents the results of eight dye-tracing studies. Three studies were made under high-flow conditions between Mogul, Nev., and Marble Bluff Dam near Nixon, Nev., during April–May 1999, and five studies under medium-flow conditions between Tahoe City, Calif., and Marble Bluff Dam near Nixon, Nev., during August–September 1999. Locations of the streamflow-gaging stations and dye-study sites, are shown in figure 1; sampling and injection sites are listed in table 1. This section of the report provides an overview of the field and laboratory procedures used to collect the data, quality-assurance methods, and the results of the tracer studies.

Data Collection

Field procedures for traveltime and dispersion studies on streams using dye tracers are well documented (Kilpatrick and Wilson, 1989). In general, those procedures were followed closely during the 1999 Truckee River studies.

The five Truckee River reaches studied in 1999 were from Tahoe City, Calif., to Boca Bridge near Truckee, Calif.; from the old U.S. Highway[1] 40 bridge near Truckee, Calif., to Mogul, Nev.; from Mogul, Nev., to Vista, Nev.; from Steamboat Creek at its mouth near Sparks, Nev., to Wadsworth, Nev.; and from Wadsworth, Nev., to Marble Bluff Dam near Nixon, Nev. For each study reach, a minimum of three sampling sites downstream from the injection point

[1]Old U.S. Highway 40 is now known as Glenshire Road.

Table 1. Truckee River traveltime-study injection and sampling sites and selected U.S. Geological Survey (USGS) streamflow gaging stations

[River miles are based on Brown and others (1986). —, not applicable]

Site number used in this report	U.S. Geological Survey site				Purpose of site in this study	Remarks
	Station number	Name	Location			
			River miles above Marble Bluff Dam	Latitude and longitude		
1	10337500	Truckee River State Route 89 bridge at Tahoe City, Calif.	116.25	39°09′59″ N. 120°08′36″ W.	Injection	Dye injected from downstream side of State Route 89 bridge, about 260 feet (0.05 mile) upstream from USGS gaging station.
2	—	Truckee River below Squaw Creek near Tahoe City, Calif.	110.10	39°12′42″ N. 120°11′54″ W.	Sampling	Sampled near left bank downstream from private bridge below Squaw Creek.
3	10338000	Truckee River near Truckee, Calif.	103.62	39°19′14″ N. 120°17′47″ W.	Sampling	Sampled near left bank at USGS gaging station.
4	10339010	Truckee River at State Route 267 at Truckee, Calif.	100.86	39°19′36″ N. 120°11′00″ W.	Sampling	Sampled near right upstream bank.
5	10339498	Truckee River at Glenshire Road (old U.S. 40) bridge below Truckee, Calif.	96.14 96.17	39°21′11″ N. 120°07′17″ W.	Injection Sampling	Dye injected at upstream side of new Glenshire Road bridge, which is 0.01 mile upstream from old U.S. 40 bridge. Samples collected near right bank about 200 feet (0.04 mile) upstream from old bridge.
6	10344505	Truckee River at Boca Bridge near Truckee, Calif.	91.24	39°23′07″ N. 120°05′12″ W.	Sampling	Sampled near left bank at old Boca Bridge, which is about 30 feet downstream from new Boca Bridge.
7	10346000	Truckee River at Farad, Calif.	81.89	39°25′41″ N. 120°01′59″ W.	Sampling	Sampled near left bank at USGS gaging station
8	10347320	Truckee River at Bridge Street bridge at Verdi, Nev.	73.50	39°31′27″ N. 119°59′32″ W.	Sampling	Sampled upstream near right bank.
9	10347460	Truckee River near Mogul, Nev.	68.74	39°30′26″ N. 119°55′51″ W.	Injection and sampling.	Dye injected from downstream side of bridge, at USGS gaging station. Samples collected near left bank at USGS gaging station.
10	—	Truckee River above West McCarran Boulevard bridge at Reno, Nev.	63.97	39°30′40″ N. 119°51′41″ W.	Sampling	Sampled near right bank about 570 feet (0.11 mile) upstream from bridge.
11	10348000	Truckee River at Reno, Nev.	59.07	39°31′53″ N. 119°47′07″ W.	Sampling	Sampled at USGS gaging station near left bank.
12	—	Steamboat Creek at mouth near Sparks, Nev.	53.53	39°31′53″ N. 119°47′07″ W.	Injection	Dye injected near right bank of Steamboat Creek at mouth.
13	10350000	Truckee River at Vista, Nev.	53.38	39°31′14″ N. 119°42′00″ W.	Sampling	Sampled near right bank about 500 feet (0.09 mile) below USGS gaging station.
14	10350200	Truckee River at Patrick, Nev.	44.92	39°32′49″ N. 119°34′59″ W.	Sampling	Sampled upstream from bridge near left bank in April 1999 and near right bank in August 1999.
15	10350340	Truckee River near Tracy, Nev.	42.75	39°33′24″ N. 119°33′08″ W.	Gaging station	USGS gaging station used to determine discharge.
16	10350400	Truckee River below Tracy, Nev.	40.62	39°33′52″ N. 119°31′02″ W.	Sampling	Sampled near left bank at pre-1997 gaging station site.
17	10351600	Truckee River below Derby Dam near Wadsworth, Nev.	34.49	39°35′05″ N. 119°26′25″ W.	Sampling	Sampled near right bank at USGS gaging station.
18	10351648	Truckee River at old U.S. 40 bridge, Wadsworth, Nev.	23.69	39°37′55″ N. 119°16′54″ W.	Injection and sampling.	Dye injected at downstream side of bridge. Sampled near left bank upstream of bridge.
19	10351690	Truckee River at Dead Ox Wash near Nixon, Nev.	13.18	39°44′14″ N. 119°19′24″ W.	Sampling	Sampled near left bank about 300 feet (0.06 mile) downstream from wash.
20	10351700	Truckee River near Nixon, Nev.	9.42	39°46′40″ N. 119°20′10″ W.	Gaging station	USGS gaging station used to determine discharge.
21	10351750	Truckee River at State Route 447 at Nixon, Nev.	3.22	39°49′45″ N. 119°21′36″ W.	Sampling	Sampled near left bank upstream of bridge.
22	10351780	Truckee River below Marble Bluff Dam near Nixon, Nev.	.05	39°51′11″ N. 119°23′44″ W.	Sampling	Sampled near right bank during April 1999 and near left bank during August 1999.

were selected. Accessibility and suitability for making streamflow measurements over a range of flows were considered in site selection. Sampling sites were far enough downstream from the injection sites that complete lateral mixing could be assumed. Tributary inflows, analogous to a side injection of clear water, cause lateral-mixing problems at nearby downstream sampling sites. Dye-measurement sites were chosen to be sufficiently downstream from tributary inflows for the water and dye to be fully mixed. Despite these precautions, Little Truckee River and Steamboat Creek inflows may have caused poor mixing at Boca Bridge near Truckee (site 6) and at Vista (site 13), respectively, during the medium-flow studies.

Single-slug (instantaneous) dye injections usually were made near the center of active flow. Rhodamine WT dye was used in the studies because it is less susceptible than other dye types to loss by contact with aquatic plants, suspended clays, and the streambed and streambanks. For each injection, the type and amount of dye, time and location of injection, and the measured streamflow were recorded. The amount of dye to be injected at the upstream end of each study reach was determined by using general empirical relations (Kilpatrick and Wilson, 1989) that are dependent upon the maximum streamflow anticipated for the reach, velocity, reach length, and dye concentration. These dye amounts typically were chosen so peak concentrations at the downstream end of each study reach or at municipal water intakes did not exceed 10 µg/L.

Fluorometers were used in the field and in the laboratory to determine the presence and concentration of dye in the samples collected. Fluorometers measure the luminescence of a fluorescent substance when that substance is subjected to a light source of an appropriate wavelength. The higher the concentration of the fluorescent substance, the more emitted light the fluorometer detects. Control samples taken at each site indicate that the background concentration was 0.04 µg/L or less in the river. When the dye plume arrived at a given site, 14 to 34 samples were taken in the main flow of the river at time intervals adequate to define the time–concentration (response) curve. Samples were collected manually at single points in the river. Fluorometer measurements were made in the field at the time of sampling to guide the frequency and duration of sampling for each dye plume. After field measurement, samples were stored out of sunlight in 1-oz glass bottles for later analysis under laboratory conditions.

Streamflow measurements were made at the injection site and at each sampling site. In those instances where direct streamflow measurements were not made while dye was present, streamflow-gaging-station data from nearby stations were substituted or were used to estimate the flow within a reach during the period when dye was present. Also, diversion data (20 sites) and return data (4 sites) were obtained from the Federal Water Master, Dave Wathen (U.S. District Court, written commun., 1999). In the reach from Farad (site 7) to Mogul (site 9) about 18 percent of the flow was diverted from the Truckee River for irrigation and municipal uses during September. During August about 130 ft^3/s was diverted through the Truckee Canal, which is upstream from the sampling site below Derby Dam near Wadsworth (site 17).

The samples collected in the field were reanalyzed under more-controlled laboratory conditions because sample temperatures experienced in the field varied and were different from those used to calibrate the fluorometer. Aside from dye concentration, sample temperature is the most significant factor affecting the fluorescence of a dilute solution. The fluorometer was calibrated in the lab according to procedures described by Wilson and others (1986) using standard solutions prepared from the same dye lot that had been used in the field. The raw data shown in tables and used in figures in this report are the actual dye-concentration values that were obtained under laboratory conditions; they were not adjusted to conservative values on the basis of dye-recovery percentages.

Quality Assurance

Quality-assurance procedures used in this study involved comparing field and laboratory measurements of dye concentrations, analyzing plots of dye concentrations, and conserving dye mass.

In general, dye-concentration values recorded in the laboratory differed slightly from those measured in the field; however, the trend in concentration was consistent between field and laboratory values.

Plotted dye concentrations were compared to expected patterns and within a given reach. The dye curves were similar to those presented by Kilpatrick and Wilson (1989, p. 3), in that the peak concentration was reduced and the dye plume increased in length as it moved downstream.

In addition to streamflow measurements and U.S. Geological Survey (USGS) gaging-station data, data on agricultural and municipal diversions (20 sites) and

on returns (4 sites) were obtained from the files of the Federal Water Master, Dave Wathen (U.S. District Court, written commun., 1999).

The amount of dye recovered at each sampling site was determined on the basis of measured streamflows and on dye concentrations. Recovered amounts were compared to the amounts of dye injected and amounts of dye recovered at other sites within the same study.

Dye-Tracing Results

Data collected during the 1999 studies are presented in tables 2 through 9 and are plotted in figures 2 through 9. The tabulated data include injection place, time, and volume; sampling sites, and distance from injection; and streamflows during sampling period; sampling times; and dye concentrations. The dye-concentration values show the amount of dispersal in the dye plume and the timing and location of the peak concentration.

Data for the Truckee River reach from Tahoe City, Calif., to Boca Bridge near Truckee, Calif., is presented in table 8; for the reach from the old U.S. Highway 40 bridge near Truckee, Calif., to Mogul, Nev., in table 9; for Mogul, Nev., to Vista, Nev., in tables 2 and 5; for Steamboat Creek at its mouth near Sparks, Nev., to Wadsworth, Nev., in tables 3 and 6; and for Wadsworth, Nev., to Marble Bluff Dam near Nixon, Nev., in tables 4 and 7.

During the high-flow study regime, flows ranged from 2,130 to 2,780 ft^3/s (tables 2 through 4). For the sites at Patrick and below Tracy (sites 14 and 16, table 3), discharges had to be estimated on the basis of discharge measurements made at the USGS streamflow-gaging station near Tracy (site 15). For the site below Marble Bluff Dam near Nixon (site 22, table 4), the no initial background sample was collected, the first sampling was done after the dye had arrived and possibly after the peak had passed.

Where either the first sample at a site was collected after the dye had arrived or the last sample, before the dye concentrations reached 0.2 µg/L, the values were derived from graphical analyses of the raw data according to the methods described by Kilpatrick and Wilson (1989).

During the medium-flow study regime, flows ranged from 173 to 627 ft^3/s (tables 5 through 9). As at high flow, for the site at Patrick (site 14, table 6) streamflow was estimated from data collected at the USGS streamflow-gaging station near Tracy (site 15). Similarly, discharge measurements for the sites at State Highway 447 at Nixon and below Marble Bluff Dam near Nixon (sites 21 and 22, table 7) were estimated from data collected at the USGS streamflow-gaging station near Nixon (site 20). Discharge measurements also could not be made at Boca Bridge near Truckee (site 6, table 9); streamflow was estimated from data collected at nearby USGS gaging stations.

Variations in discharge between sites are mostly the result of diversions and tributaries between sites. In particular, the drop in discharge between the sites below Tracy and below Derby Dam near Wadsworth (sites 16 and 17, tables 3 and 6) is mostly flow being diverted to the Truckee Canal. The increase in discharge between the sites below Derby Dam near Wadsworth and at Wadsworth (sites 17 and 18, table 3) is largely due to releases from the Truckee Canal within this reach. The decrease in discharge between the sites at Farad and at Bridge Street bridge at Verdi (sites 7 and 8, table 9) is due in large part to a diversion for hydropower, which returns the water above the site near Mogul (site 9, table 9).

As the dye travels downstream, the concentration is reduced from its peak and the dye plume takes longer to pass each site. For example, during high-flow conditions on the reach between Mogul and Vista (table 2), the peak concentrations at the site above West McCarran Boulevard bridge (site 10) was 23.0 µg/L; at Reno (site 11), 15.0 µg/L; and at Vista (site 13), 8.5 µg/L. For each sampling site, the amount of time that the dye concentration was greater than 10 percent of the peak concentration was about 40 minutes at the site above West McCarran Boulevard bridge, about 50 minutes at Reno, and about 1 hour and 15 minutes at Vista. The other dye-study reaches show a similar pattern.

Because the dye plume moved more slowly during medium-flow than during high-flow conditions, it took longer for the dye to pass each site. As an example of such traveltime characteristics, during high-flow conditions, the elapsed time for the dye to travel from the injection point near Mogul (site 9) to its peak concentration at Vista (site 13, table 2) was about 5 hours; during medium-flow conditions, traveltime for the same reach was about 11 hours (table 5). For each sampling site, the amount of time that the dye concentration was greater than 10 percent of the peak concentration was about 1 hour and 10 minutes at the site above West McCarran Boulevard bridge (site 10), about 2 hours at Reno (site 11) and 2 hours and 50 minutes at Vista. A comparison of the medium- and high-flow traveltimes for the reach between Steamboat Creek mouth near

Sparks and Wadsworth (tables 3 and 6) and for the reach between Wadsworth and Marble Bluff Dam (tables 4 and 7) show similar patterns.

SUMMARY

In 1999, eight dye-tracing studies were done during two flow regimes on the Truckee River between Tahoe City, Calif., and Marble Bluff Dam near Nixon, Nev. (approximately 3 mi upstream from Pyramid Lake). Three studies were made during high flow, (greater than 2,000 ft^3/s), and five studies were made during medium flow (173 to 627 ft^3/s). The high-flow studies were done during April and May, and the medium-flow studies were done during August and September.

The five Truckee River reaches studied were from Tahoe City, Calif., to Boca Bridge near Truckee, Calif.; from the old U.S. Highway 40 bridge near Truckee, Calif., to Mogul, Nev.; from Mogul, Nev., to Vista, Nev.; from Steamboat Creek at its mouth near Sparks, Nev., to Wadsworth, Nev.; and from Wadsworth, Nev., to Marble Bluff Dam near Nixon, Nev.

The results document the traveltime characteristics of the dye plume at each of the sampling points within each study reach. As the dye moved downstream, the peak concentration was reduced and the dye plume increased in length. During medium-flow conditions, the dye took longer to pass each site and traveled more slowly than during high-flow conditions.

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Table 2. Dye-concentration data from traveltime study on Truckee River between Mogul, Nev., and Vista, Nev., May 4, 1999

Injection site: Truckee River near Mogul, Nev. (site number 9)
Date and time of injection: May 4, 1999, at 0900
Volume of injected dye, in liters: 7.67

Sampling site:			
Name	Truckee River above West McCarran Boulevard bridge at Reno, Nev.	Truckee River at Reno, Nev.	Truckee River at Vista, Nev.
Number	10	11	13
Distance downstream from *injection site*, in river miles.	4.77	9.67	15.36
Streamflow during sampling period, in cubic feet per second.	[1]2,300	2,130	2,350
Date	May 4, 1999	May 4, 1999	May 4, 1999

Rhodamine WT dye, in micrograms per liter

Time of day	Concentration	Time of day	Concentration	Time of day	Concentration
1010	0.03	1124	[1]0.0	1320	0.04
1015	1.5	1130	.62	1330	.28
1017	4.9	1135	1.0	1335	1.2
1019	9.4	1137	2.7	1340	2.3
1021	14	1139	4.1	1345	4.0
1023	18	1142	8.0	1350	6.4
1025	21	1145	12	1355	7.1
1027	23	1148	13	1400	8.5
1029	21	1151	15	1405	7.3
1031	20	1154	15	1410	7.0
1033	16	1157	14	1415	5.4
1035	14	1200	12	1420	4.2
1038	8.9	1203	11	1425	3.1
1041	6.5	1208	5.7	1430	2.2
1044	4.2	1213	4.2	1435	1.5
1047	2.8	1218	2.7	1440	1.1
1050	1.6	1223	1.8	1445	.70
1057	.60	1228	1.0	1450	.48
1100	.35	1233	.58	1455	.35
		1238	.38	1500	.23
		1243	.23		

[1]Estimated.

Table 3. Dye-concentration data from traveltime study on Truckee River between Steamboat Creek at mouth near Sparks, Nev., and Wadsworth, Nev., April 30–May 1, 1999

Injection site: Truckee River at Steamboat Creek at mouth near Sparks, Nev. (site number 12)
Date and time of injection: April 30, 1999, at 1025
Volume of injected dye, in liters: 10.2

Sampling site: Name	Truckee River at Patrick, Nev.	Truckee River below Tracy[1]	Truckee River below Derby Dam near Wadsworth, Nev.	Truckee River at Wadsworth, Nev.
Number	14	16	17	18
Distance downstream from injection site, in river miles.	8.61	12.91	19.04	29.84
Streamflow during sampling period, in cubic feet per second.	[2]2,460	[2]2,480	2,170	2,500
Date	April 30, 1999	April 30, 1999	April 30, 1999	April 30–May 1, 1999

Rhodamine WT dye, in micrograms per liter

Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration
1255	0.02	1500	0.04	1700	0.02	1945	0.02
1305	.04	1515	2.0	1715	.03	2000	.03
1315	.03	1520	4.2	1730	.12	2015	.04
1325	.58	1530	8.1	1745	1.5	2030	.04
1335	5.6	1535	8.4	1755	1.5	2050	.04
1340	9.0	1540	10	1805	2.6	2110	.23
1345	11	1545	10	1815	3.4	2130	1.4
1350	12	1550	9.8	1820	3.7	2150	2.1
1355	11	1555	7.4	1825	3.8	2210	3.0
1400	9.2	1605	5.5	1830	3.8	2230	2.4
1405	7.6	1615	3.0	1835	3.6	2250	2.0
1410	5.1	1625	1.7	1840	3.4	2310	1.4
1415	3.6	1635	.75	1850	2.8	2330	1.1
1420	2.6	1645	.42	1900	2.3	2350	.85
1425	1.8	1655	.21	1910	2.1	0010	.76
1435	.75			1920	1.7	0030	.62
1445	.37			1930	1.4	0050	.60
1455	.20			1940	1.2	0110	.44
1505	.15			1950	1.0	0207	[2].2
1515	.10			2000	.86		
				2015	.75		
				2030	.66		
				2045	.64		
				2100	.54		
				2120	.40		
				2140	.39		
				2219	[2].2		

[1]Powerplant near Tracy, Nev.

[2]Estimated.

Table 4. Dye-concentration data from traveltime study on Truckee River between Wadsworth, Nev., and Marble Bluff Dam near Nixon, Nev., April 28, 1999

Injection site: Truckee River at Wadsworth, Nev. (site number 18)
Date and time of injection: April 28, 1999, at 0910
Volume of injected dye, in liters: 14.82

Sampling site: Name	Truckee River at Dead Ox Wash near Nixon, Nev.	Truckee River at State Highway 447 at Nixon, Nev.	Truckee River below Marble Bluff Dam[1]
Number	19	21	22
Distance downstream from injection site, in river miles.	10.51	20.47	23.74
Streamflow during *sampling period*, in cubic feet per second.	2,780	2,720	2,720
Date	April 28, 1999	April 28, 1999	April 28, 1999

Rhodamine WT dye, in micrograms per liter

Time of day	Concentration	Time of day	Concentration	Time of day	Concentration
1225	0.13	1535	0.09	1716	[2]0
1247	4.2	1550	.95	1755	6.1
1257	7.4	1605	1.1	1815	5.0
1307	10	1620	4.0	1835	3.1
1317	9.2	1635	6.6	1855	1.6
1327	7.8	1650	7.0	1915	1.1
1337	5.5	1705	5.5	1935	.66
1347	3.4	1720	3.6	1955	.35
1357	2.2	1735	2.2	2015	.28
1407	1.7	1750	1.5	2035	.24
1417	1.1	1805	.88	2055	.19
1427	.83	1820	.60	2115	.17
1437	.53	1835	.37	2135	.17
1447	.45	1850	.27	2155	.18
1457	.34	1905	.23	2215	.09
1507	.26	1935	.14	2235	.10
1516	[2].2	1950	.12	2255	.11
				2315	.09
				2335	.09
				2345	.08

[1]Near Nixon, Nev.

[2]Estimated.

Table 5. Dye-concentration data from traveltime study on Truckee River between Mogul, Nev., and Vista, Nev., August 25, 1999

Injection site: Truckee River near Mogul, Nev. (site number 9)
Date and time of injection: August 25, 1999, at 0815
Volume of injected dye, in liters: 2.65

Sampling site:			
Name	Truckee River above West McCarran Boulevard bridge at Reno, Nev.	Truckee River at Reno, Nev.	Truckee River at Vista, Nev.
Number	10	11	13
Distance downstream from injection site, *in river miles.*	4.77	9.67	15.36
Streamflow during sampling period, in cubic feet per *second.*	432	417	490
Date	August 25, 1999	August 25, 1999	August 25, 1999

Rhodamine WT dye, in micrograms per liter					
Time of day	Concentration	Time of day	Concentration	Time of day	Concentration
1040	0.02	1307	0.05	1728	0.04
1052	2.3	1317	.07	1745	.06
1057	5.4	1327	.50	1800	.23
1102	10	1332	1.2	1809	.38
1107	12	1339	2.4	1820	.78
1112	14	1246	4.1	1830	1.4
1117	14	1352	6.1	1840	2.1
1122	13	1359	7.6	1850	2.8
1127	11	1405	8.6	1900	3.1
1137	7.2	1410	9.2	1910	3.8
1147	3.4	1415	9.4	1920	4.0
1157	2.0	1420	9.3	1930	3.8
1207	1.0	1425	8.8	1942	3.6
1217	.62	1430	8.0	1950	3.2
1227	[1].2	1435	7.2	2000	2.8
		1445	5.6	2010	2.5
		1456	3.8	2020	1.9
		1506	2.8	2041	1.4
		1521	1.4	2100	.78
		1532	.94	2120	.44
		1542	.62	2140	.25
		1557	[1].2		

[1]Estimated.

Table 6. Dye-concentration data from traveltime study on Truckee River between Steamboat Creek at mouth near Sparks, Nev., and Wadsworth, Nev., August 18–20, 1999

Injection site: Truckee River at Steamboat Creek at mouth near Sparks, Nev. (site number 12)
Date and time of injection: August 18, 1999, at 0832
Volume of injected dye, in liters: 4.55

Sampling site: Name	Truckee River at Patrick, Nev.	Truckee River below Tracy[1]	Truckee River below Derby Dam near Wadsworth, Nev.	Truckee River at Wadsworth, Nev.
Number	14	16	17	18
Distance downstream from injection site, in river miles.	8.61	12.91	19.04	29.84
Streamflow during sampling period, in cubic feet per second.	[2]570	530	470	330
Date	August 18, 1999	August 18, 1999	August 19, 1999	August 19–20, 1999

Rhodamine WT dye, in micrograms per liter

Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration
1430	0.03	1815	0.03	0015	0.03	0930	0.03
1445	.08	1830	.10	0030	.06	1000	.10
1500	.74	1845	.30	0100	.15	1030	.26
1515	2.4	1900	.88	0115	.21	1045	.44
1530	6.0	1915	2.2	0130	.38	1100	.64
1545	8.2	1930	3.6	0145	.62	1120	.90
1600	10	1945	5.4	0200	.98	1140	1.2
1615	8.8	2000	6.7	0215	1.2	1200	1.4
1630	8.0	2015	7.4	0230	1.6	1230	1.7
1645	6.0	2030	7.0	0245	2.0	1245	1.7
1700	4.4	2045	6.3	0300	2.4	1300	1.7
1715	3.0	2100	5.4	0315	2.3	1315	1.7
1730	2.0	2115	4.2	0330	2.4	1330	1.7
1745	1.2	2130	3.4	0345	2.4	1350	1.6
1800	.82	2145	2.4	0400	2.3	1410	1.5
1914	[2].2	2200	1.5	0415	2.2	1440	1.3
		2215	1.1	0430	2.1	1510	1.2
		2230	.86	0445	2.0	1550	.98
		2300	.52	0500	1.9	1650	.82
		2315	.36	0515	1.8	1830	.68
		2344	[2].2	0530	1.6	2030	.52
				0545	1.4	0338	[2].2
				0615	1.2	0715	.12
				0630	1.0		
				0645	.96		
				0700	.94		
				0715	.87		
				0730	.80		
				0745	.74		
				0815	.70		
				0830	.66		
				0920	.58		
				0935	.54		
				0950	.53		
				1432	[2].2		

[1]Powerplant near Tracy, Nev.

[2]Estimated.

Table 7. Dye-concentration data from traveltime study on Truckee River between Wadsworth, Nev., and Marble Bluff Dam near Nixon, Nev., August 16–17, 1999

Injection site: Truckee River at Wadsworth, Nev. (site number 18)
Date and time of injection: August 16, 1999, at 0832
Volume of injected dye, in liters: 3.70

Sampling site:			
Name	Truckee River at Dead Ox Wash near Nixon, Nev.	Truckee River at State Highway 447 at Nixon, Nev.	Truckee River below Marble Bluff Dam[1]
Number	19	21	22
Distance downstream from injection site, in river miles.	10.51	20.47	23.74
Streamflow during sampling period, in cubic feet per second.	469	[2]425	[2]425
Date	August 16, 1999	August 17, 1999	August 17, 1999

Rhodamine WT dye, in micrograms per liter					
Time of day	Concentration	Time of day	Concentration	Time of day	Concentration
1620	0.04	0145	0.04	0415	0.02
1635	.05	0200	.05	0430	.04
1650	.24	0215	.08	0445	.07
1705	1.4	0230	.19	0500	.13
1720	2.8	0245	.40	0515	.27
1735	4.8	0300	.72	0530	.54
1750	6.6	0315	1.3	0545	.96
1805	7.4	0400	3.2	0600	1.5
1820	7.2	0415	3.4	0615	2.1
1835	6.4	0430	4.1	0630	2.6
1850	5.4	0445	3.6	0645	2.9
1905	3.8	0500	4.2	0700	3.4
1920	3.0	0515	3.9	0715	3.8
1935	2.2	0530	3.6	0730	4.0
1950	1.6	0550	3.2	0745	3.8
2005	1.3	0610	2.6	0800	3.7
2020	.98	0640	1.8	0815	3.4
2035	.78	0710	1.3	0830	3.2
2050	.62	0740	.92	0845	2.8
2144	[2].2	0810	.64	0900	2.5
		0840	.50	0915	2.2
		0910	.34	0930	1.7
		0938	[2].2	1000	1.0
				1030	.86
				1100	.64
				1130	.48
				1200	.35
				1230	.30
				1300	.22

[1]Near Nixon, Nev.
[2]Estimated.

Table 8. Dye-concentration data from traveltime study on Truckee River between Tahoe City, Calif., and Boca Bridge near Truckee, Calif, September 14–15, 1999

Injection site: Truckee River at Tahoe City, Calif. (site number 1)
Date and time of injection: September 14, 1999, at 1900
Volume of injected dye, in liters: 2.55

Sampling site:					
Name	Truckee River below Squaw Creek near Tahoe City, Calif.	Truckee River near Truckee, Calif.	Truckee River at State Highway 267 at Truckee, Calif.	Truckee River above old U.S. 40 bridge below Truckee, Calif.	Truckee River at Boca Bridge near Truckee, Calif.
Number	2	3	4	5	6
Distance downstream from injection site, in river miles.	6.15	12.63	15.39	20.08	25.01
Streamflow during sampling period, in cubic feet per second.	[1]263	266	[1]320	346	570
Date	September 14–15, 1999	September 15, 1999	September 15, 1999	September 15, 1999	September 15, 1999

Rhodamine WT dye, in micrograms per liter

Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of day	Concentration
2315	0.03	0318	[1]0.0	0450	0.03	0759	.02	1115	0.03
2330	.79	0325	1.0	0510	.38	0812	.19	1130	.08
2340	2.5	0335	2.6	0530	1.8	0826	.32	1145	.40
2350	5.2	0355	5.9	0545	3.8	0837	.77	1200	.54
2400	8.3	0405	7.4	0555	5.1	0851	1.7	1215	.95
0010	10	0417	8.6	0605	6.2	0905	2.8	1230	1.4
0020	11	0421	8.8	0615	6.6	0910	3.7	1245	1.7
0030	11	0427	8.9	0625	7.0	0925	4.1	1300	1.9
0040	10	0432	8.8	0635	7.0	0935	5.2	1315	2.0
0055	7.9	0442	7.8	0645	6.6	0943	5.4	1330	1.8
0115	5.4	0453	7.2	0655	6.0	0953	5.5	1345	1.5
0140	3.0	0505	5.8	0705	5.2	1002	5.4	1400	1.2
0200	1.8	0515	4.8	0715	4.3	1012	5.1	1415	.99
0221	1.2	0530	3.7	0730	3.2	1021	4.6	1430	.78
0241	.76	0545	2.6	0745	2.3	1031	4.1	1445	.59
0324	[1].2	0600	1.7	0800	1.8	1041	3.7	1500	.44
		0615	1.4	0815	1.3	1051	3.1	1515	.35
		0630	1.1	0830	1.0	1106	2.4	1530	.27
		0646	.74	0845	.73	1121	1.7	1545	.24
		0700	.60	0900	.58	1136	1.3	1600	.20
		0742	[1].2	0948	[1].2	1151	1.0	1615	.16
						1206	.78	1630	.14
						1221	.58		
						1236	.50		
						1251	.39		
						1330	[1].2		

[1]Estimated.

Table 9. Dye-concentration data from traveltime study on Truckee River between old U.S. Highway 40 bridge near Truckee, Calif., and Mogul, Nev., September 19–20, 1999

Injection site: Truckee River above old U.S. 40 bridge below Truckee, Calif. (site number 5)
Date and time of injection: September 19, 1999, at 2330
Volume of injected dye, in liters: 1.10

Sampling site:				
Name	Truckee River at Boca Bridge near Truckee, Calif.	Truckee River at Farad[1]	Truckee River at Bridge Street bridge at Verdi, Nev.	Truckee River near Mogul, Nev.
Number	6	7	8	9
Distance downstream from injection site, in river miles.	4.90	14.25	22.64	27.40
Streamflow during sampling period, in cubic feet per second.	[2]627	627	173[3]	505
Date	September 20, 1999	September 20, 1999	September 20, 1999	September 20, 1999

Rhodamine WT dye, in micrograms per liter

Time of day	Concentration	Time of day	Concentration	Time of day	Concentration	Time of Day	Concentration
0100	0.05	0650	0.03	1215	0.03	1500	0.10
0130	.02	0714	.10	1230	.06	1520	.20
0200	.04	0744	1.4	1245	.05	1540	.21
0230	2.2	0750	1.8	1300	.15	1605	.40
0240	4.2	0755	2.4	1315	.40	1621	.45
0248	4.2	0800	2.6	1330	.80	1643	.50
0250	4.0	0805	2.8	1345	1.3	1701	.70
0255	3.4	0810	3.0	1400	1.7	1722	.85
0300	2.8	0815	2.6	1415	1.8	1742	.75
0305	2.2	0821	2.8	1430	1.6	1804	.72
0310	1.8	0827	2.6	1445	1.3	1824	.58
0315	1.1	0835	2.2	1500	1.0	1845	.50
0320	1.0	0850	1.4	1515	.70	1904	.40
0325	.60	0913	.60	1530	.50	1922	.40
0330	.60	0933	.30	1545	.35	1942	.35
0335	.40	0940	.20	1600	.20	2003	.31
0340	.30			1615	.15	2022	.20
0345	.20			1630	.10	2043	.20
0350	.09			1645	.08	2104	.10
				1700	.05	2133	.10

[1] Powerplant near Floriston, Calif.
[2] Estimated.
[3] Part of flow directed upstream of site for hydropower.

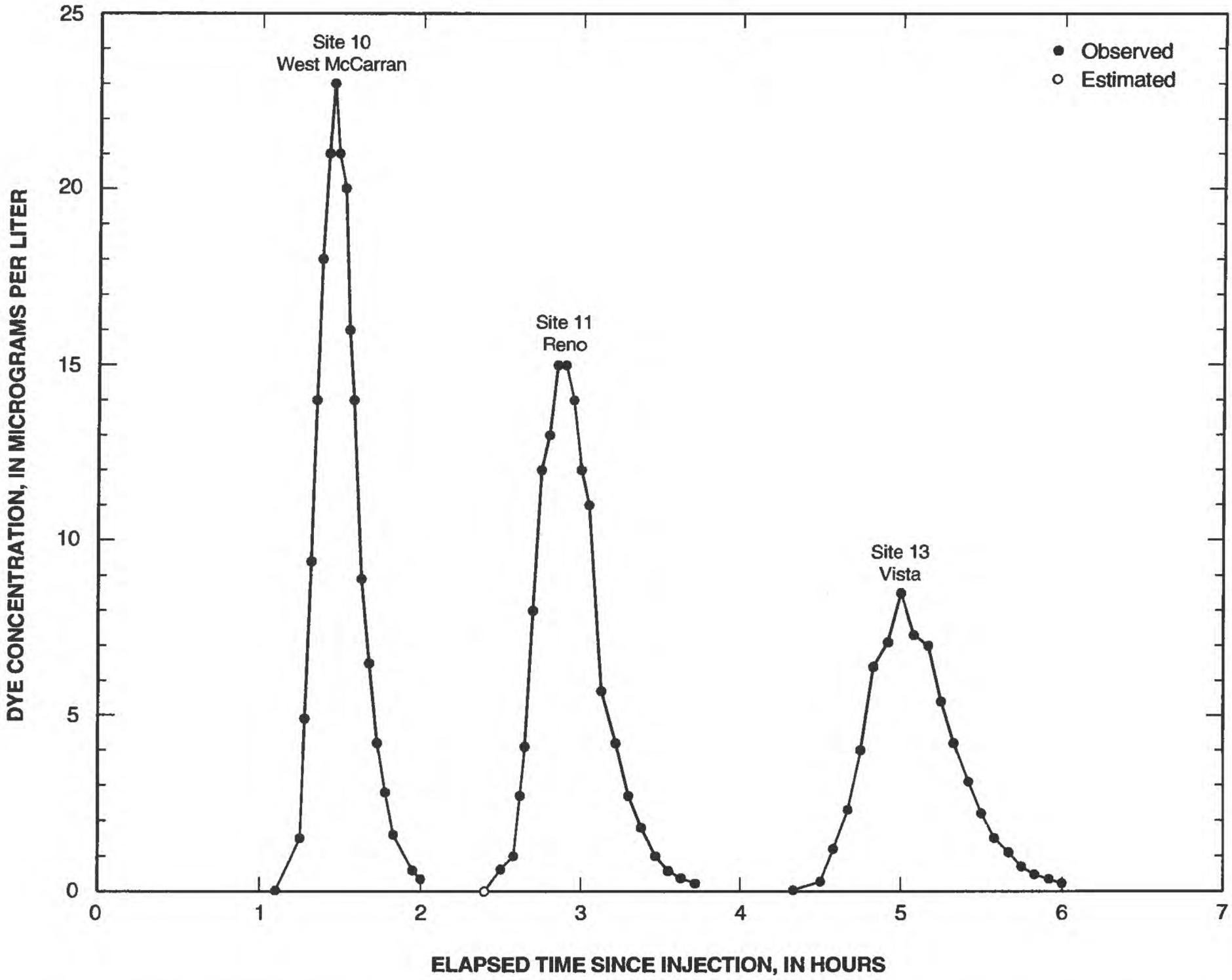

Figure 2. Observed response curves for Truckee River sites, 10, 11, and 13 for reach between Mogul, Nev., and Vista, Nev., May 4, 1999. See table 1 for full site names.

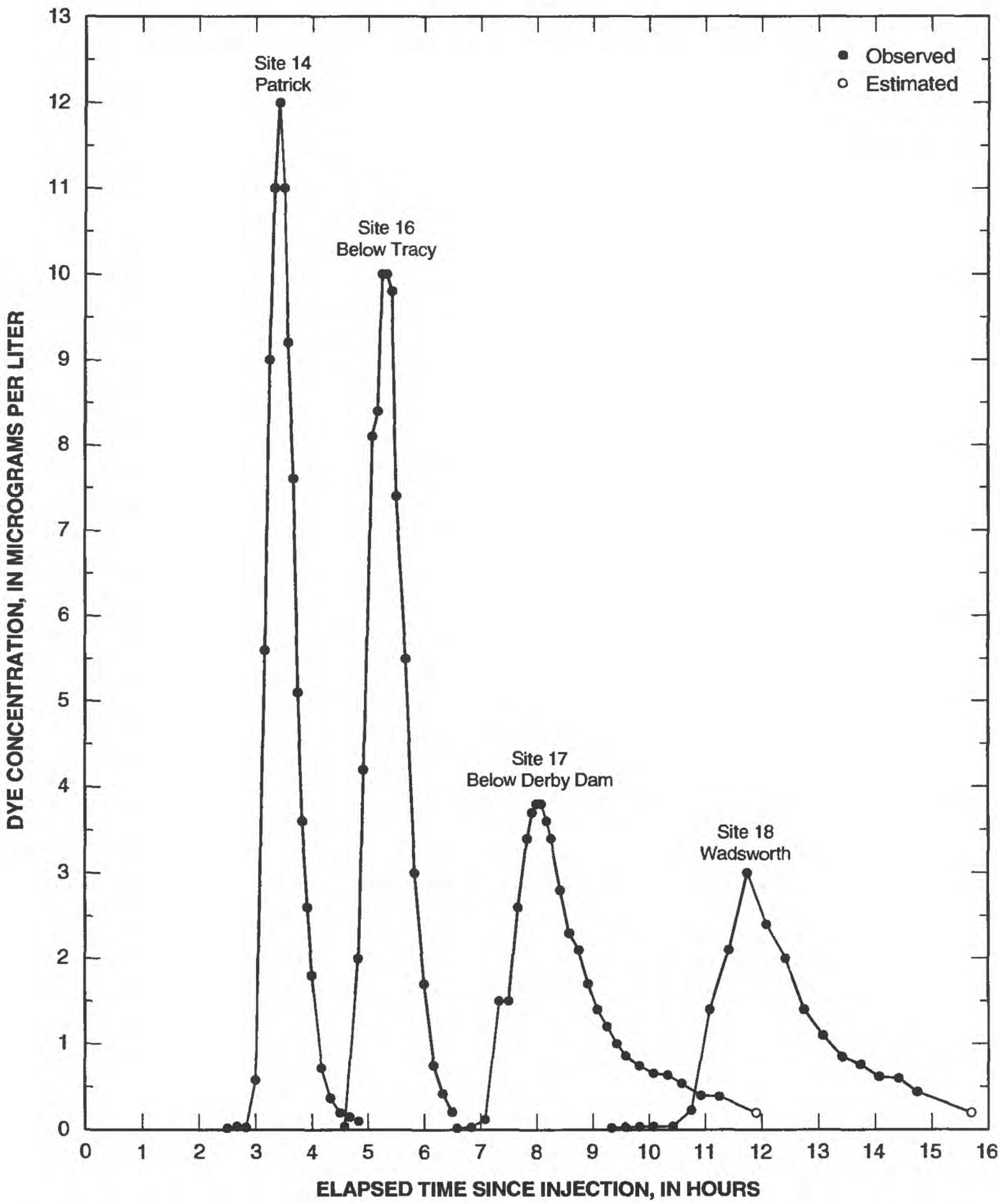

Figure 3. Observed response curves for Truckee River sites 14, 16, 17, and 18 for reach between Steamboat Creek at mouth near Sparks, Nev., and Wadsworth, Nev., April 30–May 1, 1999. See table 1 for full site names.

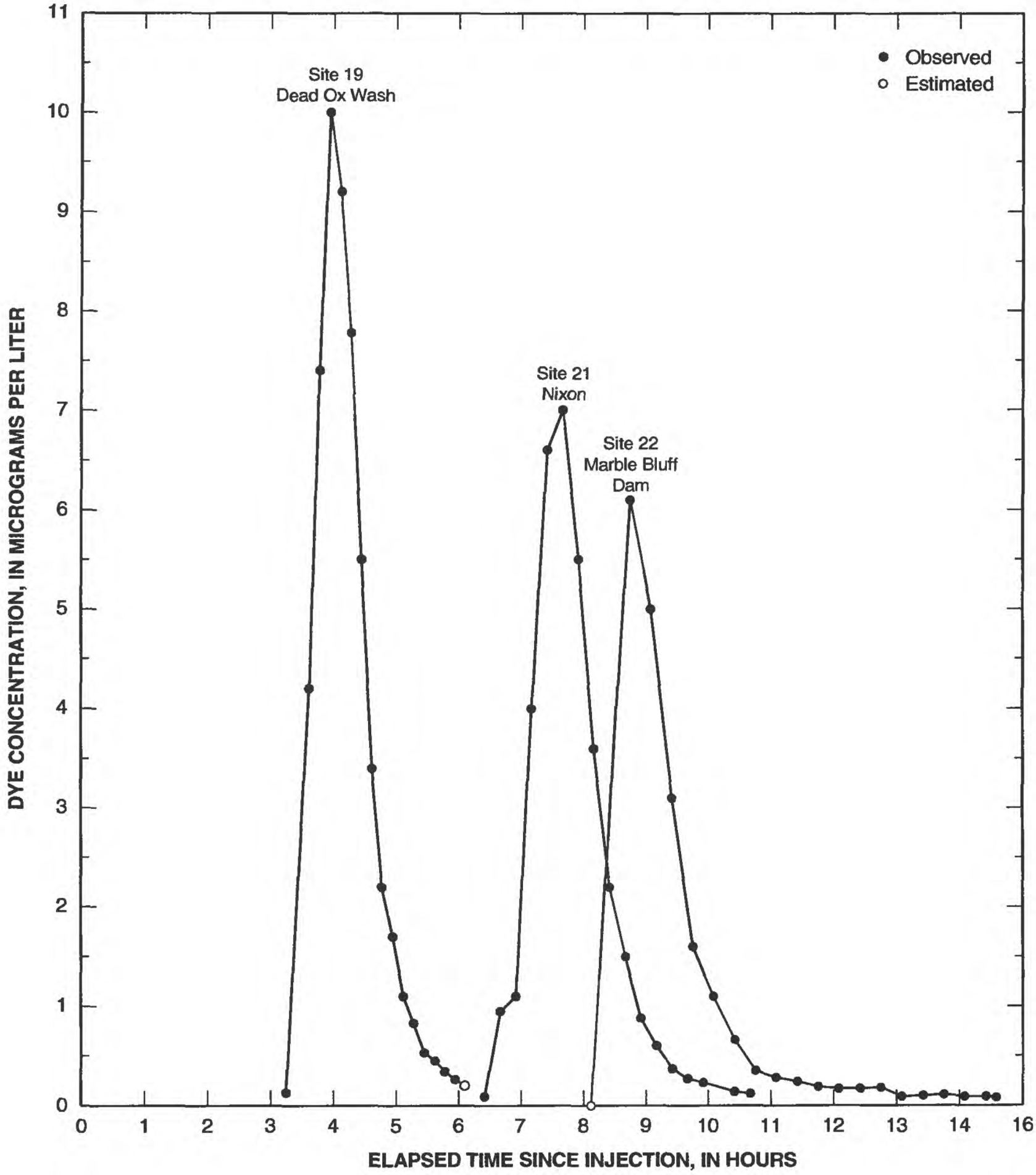

Figure 4. Observed response curves for Truckee River sites 19, 21, and 22 for reach between Wadsworth, Nev., and Marble Bluff Dam near Nixon, Nev., April 28, 1999. See table 1 for full site names.

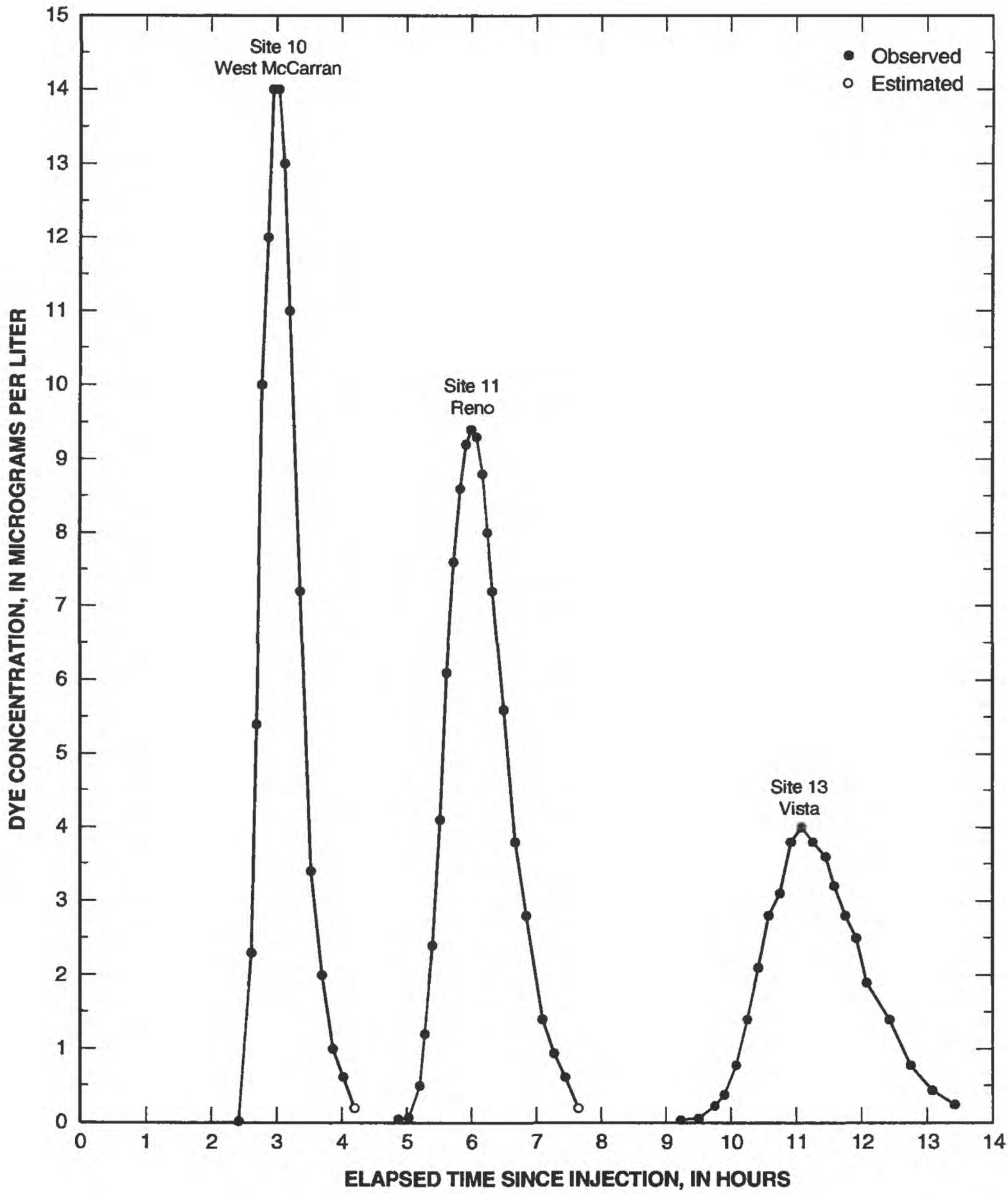

Figure 5. Observed response curves for Truckee River sites 10, 11, and 13 for reach between Mogul, Nev., and Vista, Nev., August 25, 1999. See table 1 for full site names.

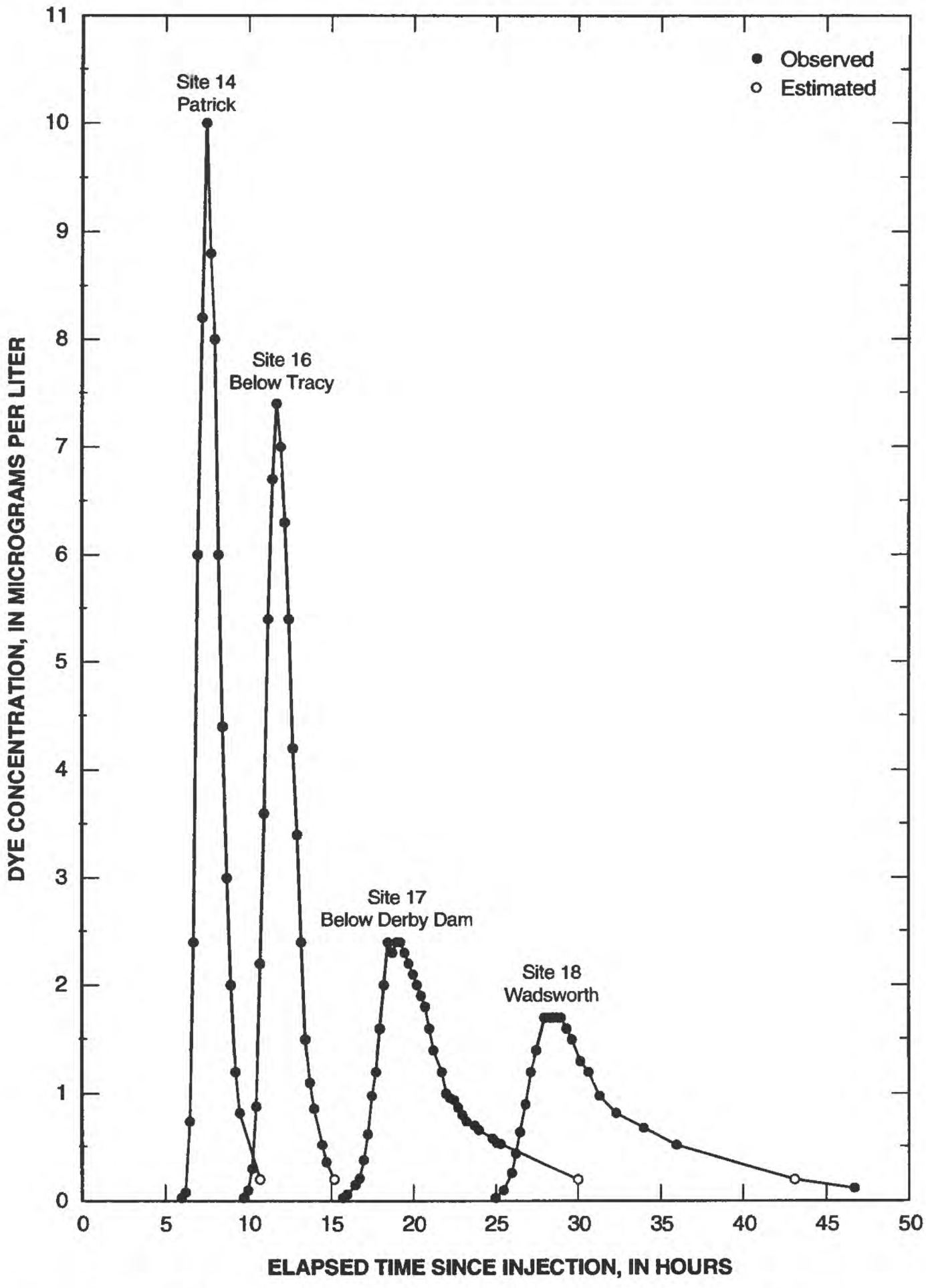

Figure 6. Observed response curves for Truckee River sites 14, 16, 17, and 18 for reach between Steamboat Creek at mouth near Sparks, Nev., and Wadsworth, Nev., August 18–20, 1999. See table 1 for full site names.

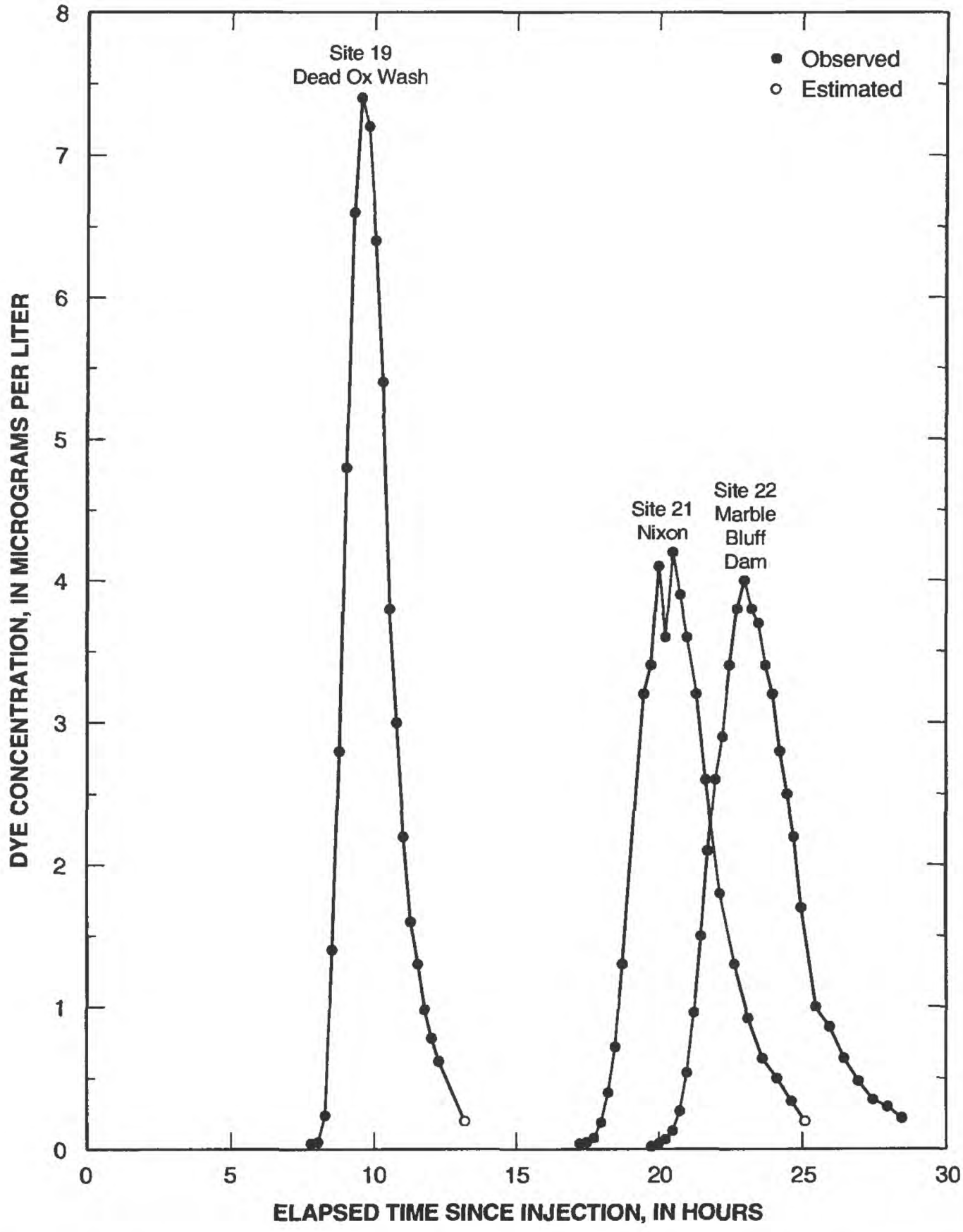

Figure 7. Observed response curves for Truckee River sites 19, 21, and 22 for reach between Wadsworth, Nev., and Marble Bluff Dam near Nixon, Nev., August 16–17, 1999. See table 1 for full site names.

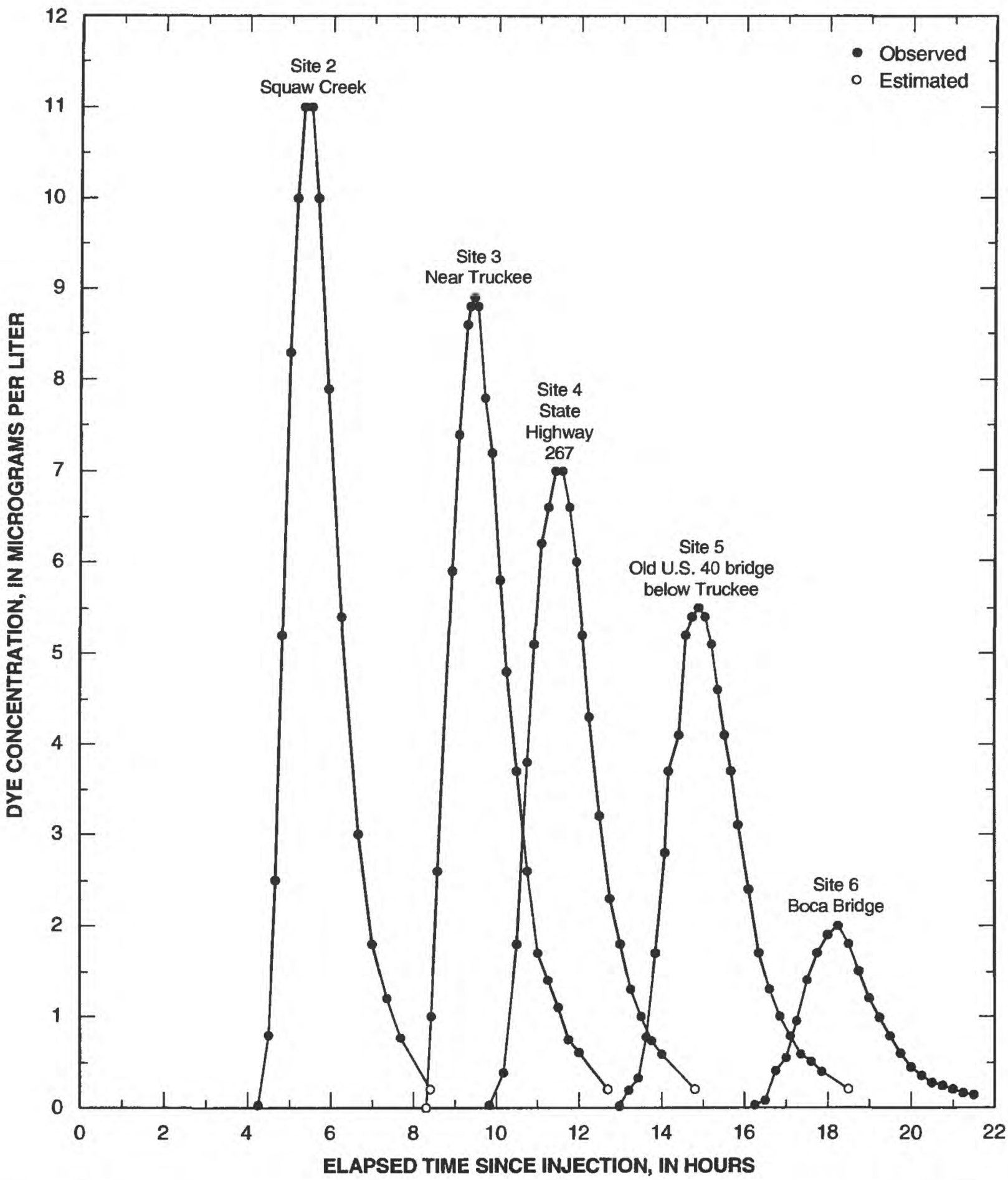

Figure 8. Observed response curves for Truckee River sites 2 through 6 for reach between Tahoe City, Calif., and Boca Bridge near Truckee, Calif., September 14–15, 1999. See table 1 for full site names.

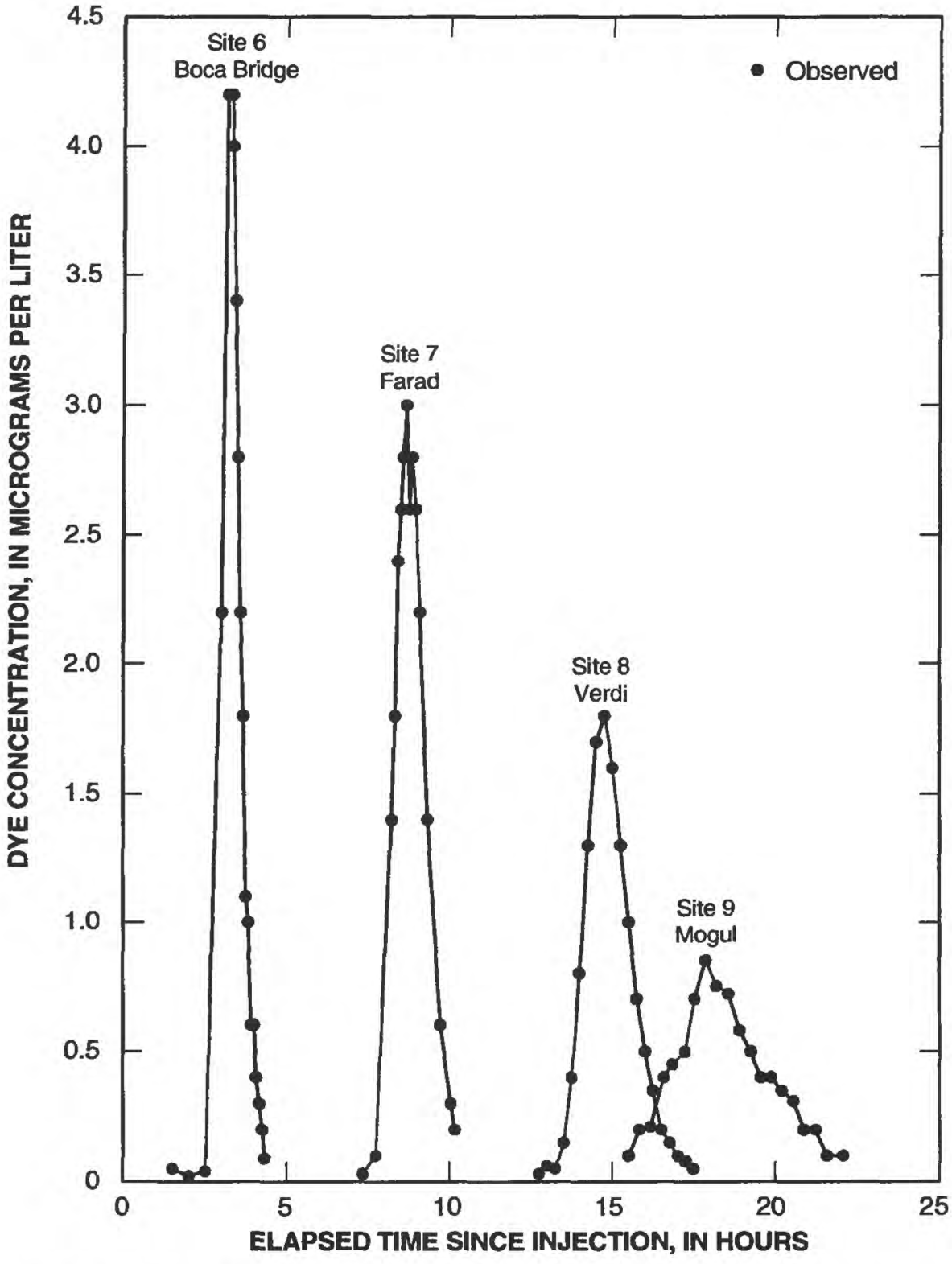

Figure 9. Observed response curves for Truckee River sites 6 through 9 between old U.S. Highway 40 bridge near Truckee, Calif., and Mogul, Nev., September 19–20, 1999. See table 1 for full site names.

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