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Dye Tracer Tests to Determine Time-of-Travel in Iowa Streams, 1990–2006

Data Series 444

U.S. Department of the Interior
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Cover Photograph. Fourmile Creek at injection site, August 2003 (photograph by Douglas J. Schnoebelen, U.S. Geological Survey).

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Contents

Figures

Table

Conversion Factors, Abbreviations, and Datum

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
foot per minute (ft/min)	0.3048	meter per minute (m/min)

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Dye Tracer Tests to Determine Time-of-Travel in Iowa Streams, 1990–2006

By Daniel E. Christiansen

Abstract

Dye-tracing tests have been used by the U.S. Geological Survey, Iowa Water Science Center to determine the time-of-travel in selected Iowa streams from 1990–2006. Time-of-travel data are tabulated for 309 miles of stream reaches in four Iowa drainage basins: the Des Moines, Raccoon, Cedar, and Turkey Rivers. Time-of-travel was estimated in the Des Moines River, Fourmile Creek, North Raccoon River, Raccoon River, Cedar River, and Roberts Creek. Estimation of time-of-travel is important for environmental studies and in determining fate of agricultural constituents and chemical movement through a waterway. The stream reaches range in length from slightly more than 5 miles on Fourmile Creek, to more than 137 miles on the North Raccoon River. The travel times during the dye-tracer tests ranged from 7.5 hours on Fourmile Creek to as long as 200 hours on Roberts Creek; velocities ranged from less than 4.50 feet per minute on Roberts Creek to more than 113 feet per minute on the Cedar River.

Introduction

The U.S. Geological Survey (USGS) Iowa Water Science Center (WSC) uses dye-tracing tests to determine time-of-travel in Iowa streams. During the past 16 years there have been several time-of-travel data-collection efforts in support of environmental studies. The purpose of this report is to summarize the time-of-travel data for Iowa streams that were collected from 1990–2006.

Time-of-travel data were collected from six stream reaches located in four drainage basins in Iowa from 1990–2006. These data included approximately 309 miles of stream reach in the drainage basins shown in figure 1. Time-of-travel data used in this report were collected and analyzed by USGS personnel. The time-of-travel data were collected for various studies to develop an understanding of instream effects on water-quality constituents, to aid in establishing water-quality sampling strategies, and to calibrate streamflow and water-quality transport models.

Methods

Each of the time-of-travel studies used similar methods to determine the travel times of solutes. The most accurate method of determining travel-times in a stream is by direct measurement using dye tracers (Kilpatrick and Wilson, 1989; Jobson, 2000). To measure time-of-travel, a volume of a tracer is injected into the stream and timed as the tracer passes downstream sampling sites. Nontoxic, fluorescent dyes typically are used in dye-tracing studies of which the degree of fluorescence in the water sample can be determined with a flourometer (Wilson, 1967). The tracer used in these studies was rhodamine WT fluorescent dye. This dye was selected because it is soluble in water, generally is easy to detect, has fluorescence in a part of the spectrum not common to materials generally detected in water, is harmless in small concentrations (Steinheimer and Johnson, 1986), and is reasonably stable in normal water environments (Wilson and others, 1986). The fluorescence measurements were made using a Turner Designs bench and submersible flourometers. Calibrations were performed by diluting stock dye used during each study to known concentrations. The dye studies were performed during stable conditions when streams were near base flow and there was minimal runoff in the basin. In addition, dye studies at three of the sites were conducted on a second date under different flow conditions to better understand the relation between time-of-travel and discharge (table 1). Sampling sites were co-located with some streamgaging stations to facilitate obtaining discharge measurements. At ungaged sampling locations, field measurements were made or discharges were estimated.

Time-of-Travel for Iowa Streams

Time-of-travel data collected for selected studies from 1990 to 2006 are compiled for this report. Time-of-travel data are available for the following drainage basins in Iowa (fig. 1):

- Des Moines River Basin (fig. 2);
- Raccoon River Basin (fig. 3);
- Cedar River Basin (fig. 4);
- Turkey River Basin (fig. 5).

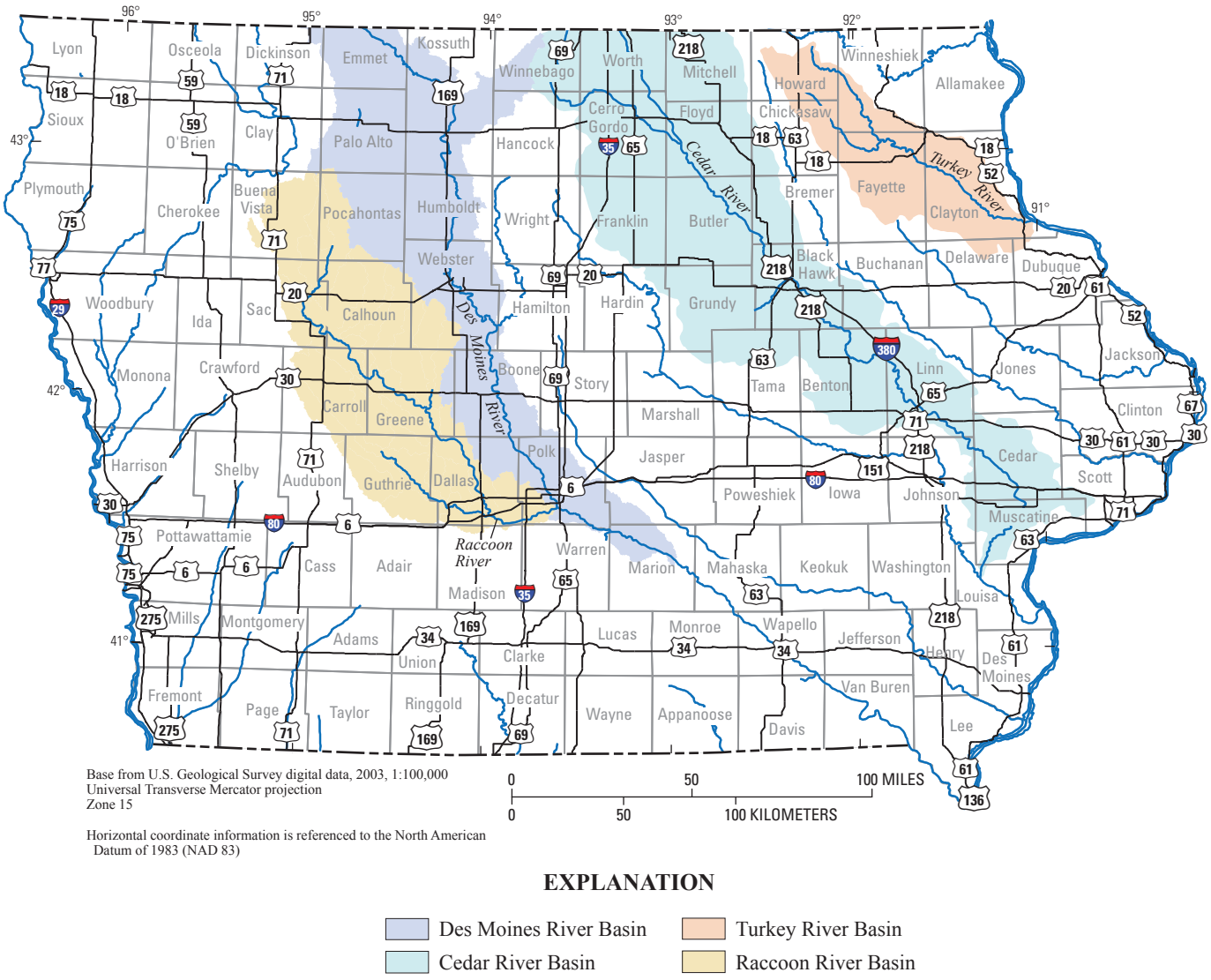

Figure 1. Location of drainage basins in Iowa with available time-of-travel data, 1990–2006.

Stream reaches with time-of-travel data are shown in figures 2–5. Time-of-travel data are summarized in table 1. The data tabulated for each stream reach includes the following parameters:

- **Date of study**—Month and year of study;
- **Reach**—Location of beginning and end of stream reach;
- **County**—Name of county where stream reach is located;
- **Latitude**—Degrees, minutes, and seconds of latitude at beginning and end of stream reach;
- **Longitude**—Degrees, minutes, and seconds of longitude at beginning and end of stream reach;
- **Length of reach**—Length of stream reach, in miles (mi);
- **Solute time-of-travel, in hours**—Elapsed travel time of peak concentration in dye cloud from the beginning to the end of the reach;
- **Rate of travel, in feet per minute**—Rate of travel time of peak concentration in dye cloud from the beginning to the end of the reach, and;
- **Stream discharge, in cubic feet per second.**

The 163.8 mile reach of the Raccoon River Basin (fig. 3) was the longest of the time-of-travel studies. The Raccoon River Basin included two time-of-travel studies, one in the North Raccoon River (137 mi), and the second in the Raccoon River (26.8 mi).

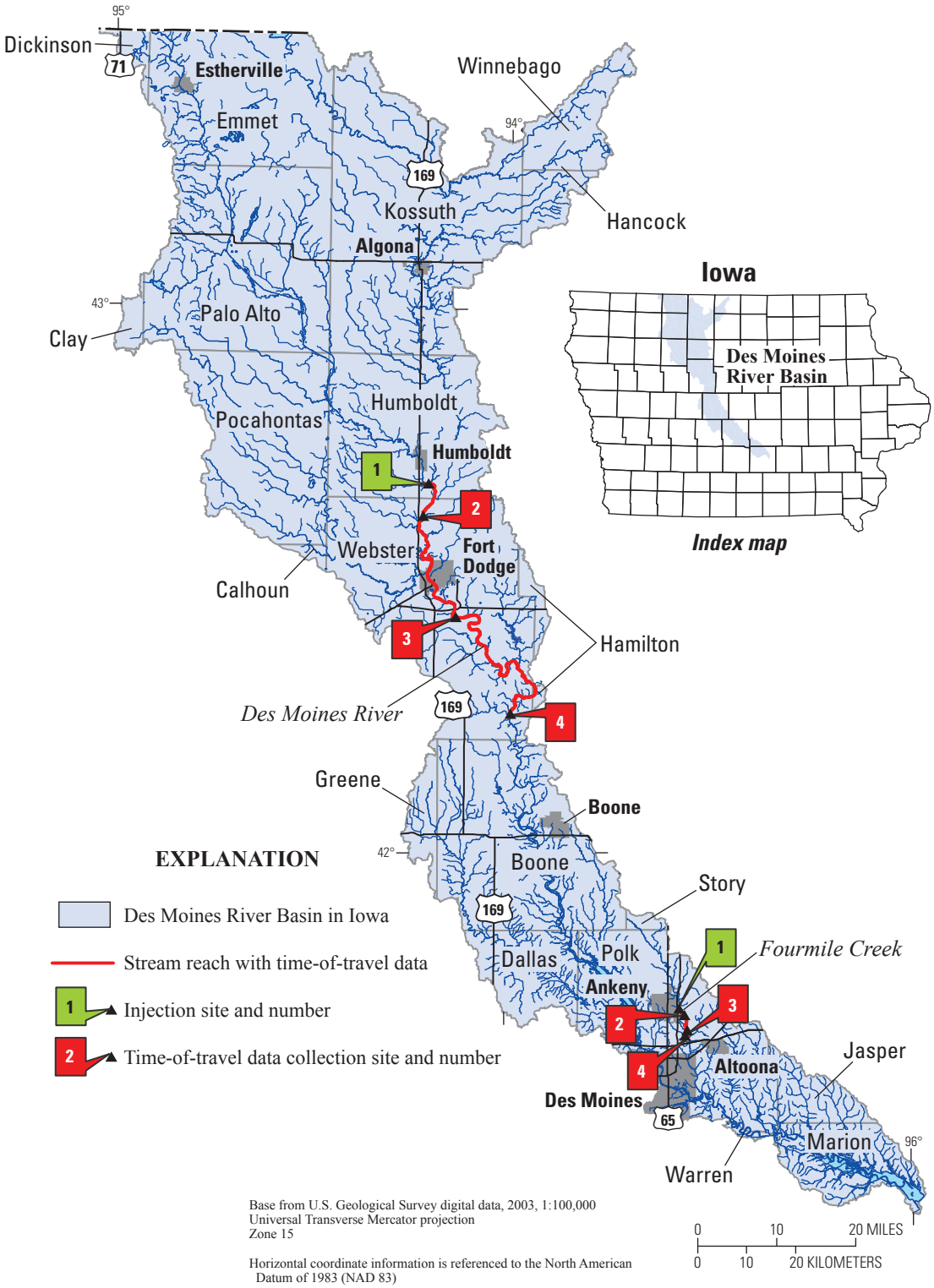

Figure 2. Location of Des Moines River Basin and stream reaches with time-of-travel data.

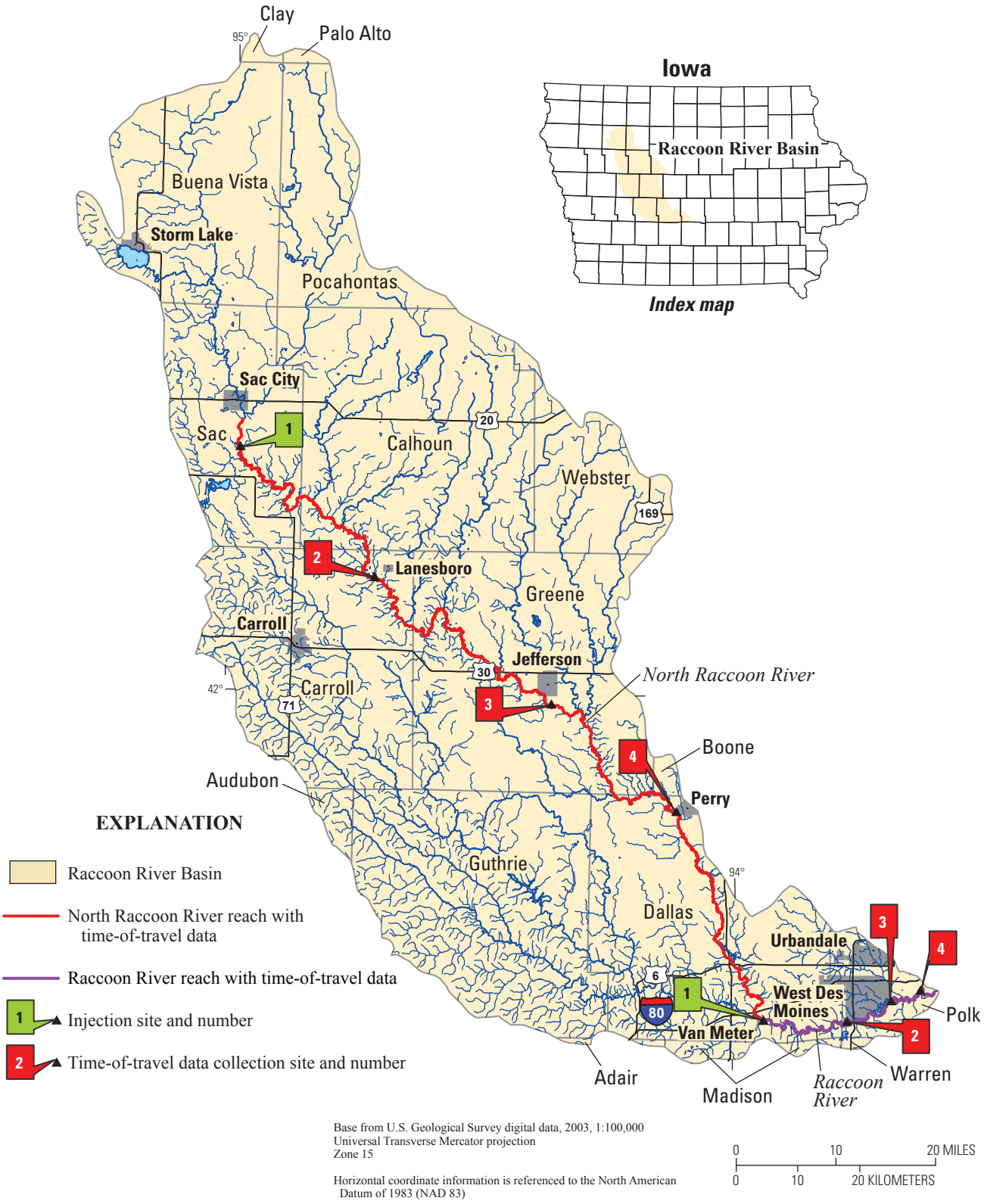

Figure 3. Location of Raccoon River Basin and stream reaches with time-of-travel data.

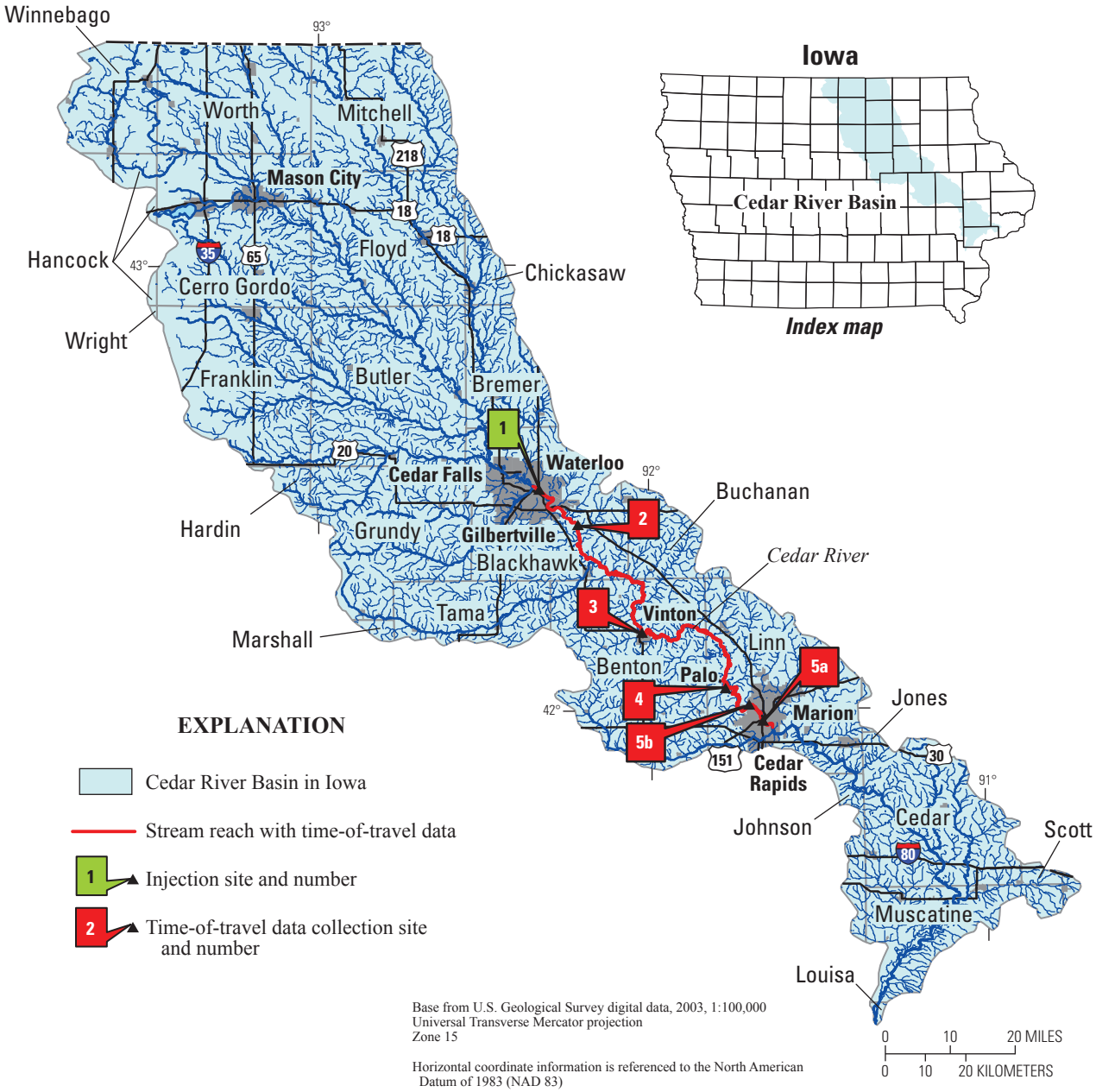

Figure 4. Location of Cedar River Basin and stream reaches with time-of-travel data.

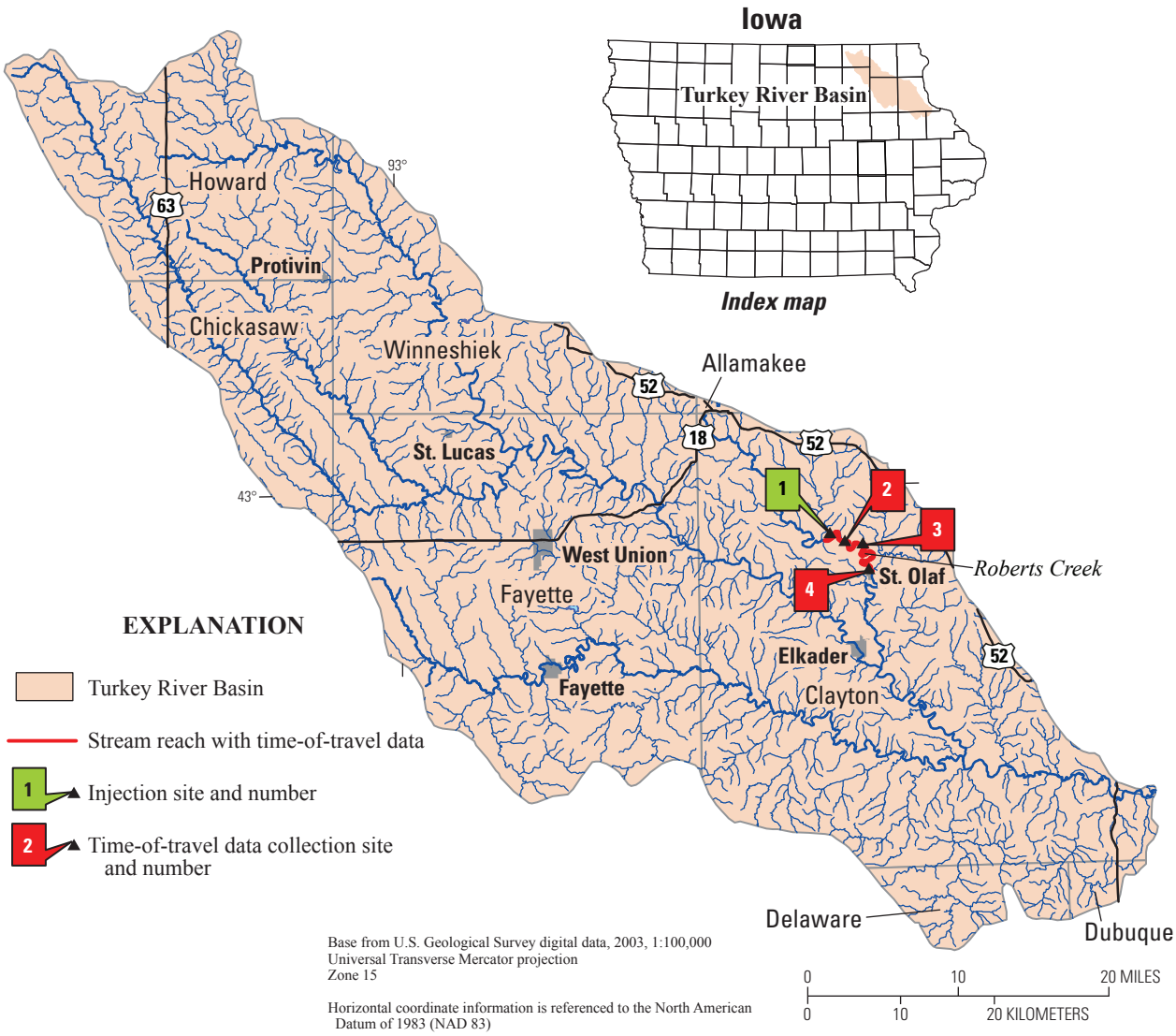

Figure 5. Location of Turkey River Basin and stream reaches with time-of-travel data.

The Cedar River Basin had the second longest time-of-travel study (75.2 mi). The Cedar River had two time-of-travel studies conducted along the same reach performed during different flow conditions.

The Des Moines River Basin had 61 mi of reach covered on two streams within the basin. The Des Moines River reach time-of-travel data that were collected within the basin covered 54.4 mi. Fourmile Creek covered 6.64 mi of stream within the Des Moines River Basin. Fourmile Creek has two time-of-travel studies performed during different flow conditions.

The Turkey River Basin has the smallest length of river miles (9.40 mi) covered of the four basins with time-of-travel data in this report. Time-of-travel data were collected during two flow conditions on a 9.40 mi reach of Roberts Creek. Time-of-travel data for Roberts Creek were published previously by Kolpin and Kalkhoff (1992).

The results of the dye tracer studies showed stream discharge during the time-of-travel study ranged from less than 5 cubic feet per second (ft^3/s) (Roberts Creek, March 1990) to more than 2,400 ft^3/s (Cedar River, October 2002). The rate of dye travel ranged from 114 feet per minute (ft/min) in the Cedar River to less than 4.40 ft/min in Roberts Creek. The rate of travel is dependant upon the stream discharge and the change in altitude along the stream reach (channel slope). Time-of-travel along the stream reaches ranged from 7.5 hours (Fourmile Creek, March 2005) to 200 hours (Roberts Creek, April/May 1990). The time-of-travel studies in this report provide useful information concerning flow and chemical movement through the systems.

Table 1. Summary of time-of-travel data collected for streams in Iowa, 1990–2006.

[hr, hour; ft/min, feet per minute; ft³/s, cubic foot per second; dddmmss, degrees minutes seconds; --, indicates not applicable or unknown; est., estimated; Stream discharge is the average discharge in reach unless otherwise noted; *, indicates discharge value from stream gage or calculated from nearest stream gage;** indicates measured discharge at site along reach]

Date of study	Reach	Site number	County	Latitude (north) ddmmss	Longitude (west) ddmmss	Length of reach (miles)	Solute time of travel (hr)	Rate of travel (ft/min)	Stream discharge (ft³/s)
Des Moines River Basin									
Des Moines River									
July 2006	County Road C49 to	1	Humboldt	424029	941226	0.00	injection	--	669*
	County Road C56 to	2	Webster	423657	941254	5.90	5:04	102.1	--
	County Road P59 to	3	Webster	422553	940758	24.4	27:42	77.4	--
	Hwy 175	4	Webster	421508	935957	54.4	82:10	58.1	928*
Fourmile Creek									
August 2003	S1, Near I35, Ankeny to	1	Polk	414309	933420	.00	injection	--	4.70**
	S4, NE 29th St, Ankeny to	2	Polk	414215	933336	1.86	6:15	26.4	11.8**
	S5, NE 62nd Ave., Ankney to	3	Polk	414023	933310	5.28	17:00	27.3	8.60**
	S6, NE 54th Ave.. Ankeny	4	Polk	413956	933257	6.64	21:30	27.3	9.7**
March 2005	S2, Near I35, Ankeny to	1	Polk	414305	933417	.00	injection	--	31.0**
	S4, NE 29th St, Ankeny to	2	Polk	414215	933336	1.80	3:00	52.8	38.3**
	S5, NE 62nd Ave., Ankney	3	Polk	414023	933310	5.22	7:30	61.6	39.6**
Raccoon River Basin									
North Raccoon River									
March 2006	County Road D46 to	1	Sac	422116	945926	.00	injection	--	264*
	Hwy 286 to	2	Carroll	421009	944332	35.1	36:48	83.6	279 est.
	Hwy 4 to	3	Greene	415917	942236	73.8	89:24 est.	73.0 est.	369*
	Hwy 141 to	4	Dallas	415007	940754	102	127:41	70.4	436 est.
	County Road R16	5	Dallas	413202	935659	137	136:48	88.0	548*
Raccoon River									
March 2006	County Road R16 to	1	Dallas	413202	935659	.00	injection	--	506*
	Near I35 to	2	Polk	413154	934654	14.6	13:59	92.4	--

Table 1. Summary of time-of-travel data collected for streams in Iowa, 1990–2006. —Continued

[hr, hour; ft/min, feet per minute; ft³/s, cubic foot per second; dddmmss, degrees minutes seconds; --, indicates not applicable or unknown; est., estimated; Stream discharge is the average discharge in reach unless otherwise noted; *, indicates discharge value from stream gage or calculated from nearest stream gage;** indicates measured discharge at site along reach]

Date of study	Reach	Site number	County	Latitude (north) ddmmss	Longitude (west) ddmmss	Length of reach (miles)	Solute time of travel (hr)	Rate of travel (ft/min)	Stream discharge (ft³/s)
				Raccoon River—Continued					
	Hwy 28 to	3	Polk	413342	934212	20.7	19:49	92.4	706*
	Fleur Drive, Des Moines	4	Polk	413454	933834	26.8	25:37	91.5	919*
				Cedar River Basin					
				Cedar River					
October 2002	11th Ave., Waterloo to	1	Black Hawk	422944	922003	.00	injection	--	2,290*
	County Road D38 to	2	Black Hawk	422457	921307	11.4	8:50	114	2,293 est.
	Hwy 150 to	3	Benton	421015	920125	38.8	30:30	112	2,351 est.
	County Road E36 to	4	Linn	420300	914630	62.0	49:31	110	2,383 est.
	8th Ave., Cedar Rapids	5a	Linn	415819	914001	75.2	60:20	110	2,410 est.
September 2003	11th Ave., Waterloo to	1	Black Hawk	422944	922003	.00	injection	--	1,045*
	County Road D38 to	2	Black Hawk	422457	921307	11.4	16:11	61.6	--
	Hwy 150 tp	3	Benton	421015	920125	38.8	44:10	77.4	--
	County Road E36 to	4	Linn	420300	914630	62.0	68:07	80.1	--
	Edgewood Road, Cedar Rapids	5b	Linn	420042	914217	71.8	85:56	73.9	--
				Turkey River Basin					
				Roberts Creek					
March 1990	RC18 to	1	Clayton	425736	912603	.00	injection	--	7.60**
	RC19 to	2	Clayton	425733	912510	2.10	12:00	15.8	--
	RC24 to	3	Clayton	425724	912358	3.95	20:00	17.6	--
	RC2	4	Clayton	425549	912303	9.40	59:00	14.1	5.50*
April/May 1990	RC18 to	1	Clayton	425736	912603	.00	injection	--	4.30**
	RC19 to	2	Clayton	425733	912510	2.10	32:00	6.16	--
	RC24 to	3	Clayton	425724	912358	3.95	50:00	7.04	--
	RC2	4	Clayton	425549	912303	9.40	200:00	4.40	1.40*

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