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Scientific Investigations Report 2005-5286

U.S. Department of the Interior
U.S. Geological Survey

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Conversion Factors

Multiply	By	To obtain
foot (ft)	0.3048	meter
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
mile (mi)	1.609	kilometer
mile per hour (mi/h)	1.609	kilometer per hour

Temperature: Degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) by using the formula

$$°F = (1.8 \times °C) + 32.$$

Discharge or flow: The rate that matter passes through a cross section of a stream channel or other water body per unit of time. The term commonly refers to the volume of water (including, unless otherwise stated, any sediment or other constituents suspended or dissolved in the water) that passes a cross section in a stream channel, flume, weir, canal, pipeline, etc., within a given period of time (cubic feet per second).

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25°C).

Datums

Sea level: In this report, “sea level” refers to the National Geodetic Vertical Datum of 1988 (NGVD of 1988, formerly called “Sea-level Datum of 1988”), which is derived from a general adjustment of the first-order leveling networks of the United States and Canada

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD83) unless otherwise stated.

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Abstract

On February 12, 2003, synoptic-discharge, water-temperature, and specific-conductance measurements in the lower Virgin River indicated net increases of 67.5 ft^3/s (cubic feet per second), 5.5°C (degrees Celsius), and 130 µS/cm (microsiemens per centimeter), respectively, between U.S. Geological Survey streamflow-gaging stations above the Virgin River Narrows and at Littlefield, Arizona. Between the gaging stations at Littlefield, Arizona, and above Lake Mead, Nevada, discharge and water-temperature measurements indicated a net decrease of 42 ft^3/s and 4.0°C, respectively, with specific conductance indicating a net increase of 450 µS/cm. General trends in discharge, water temperature, and specific conductance seem consistent with a river basin where surface water is diverted for agricultural and municipal purposes. Some of the diverted water is recycled back into the river through the shallow ground-water system downstream of the diversions.

Introduction

The Virgin River originates in Zion National Park, Utah, flows in a southwesterly direction across parts of southwestern Utah, northwestern Arizona, and southern Nevada before discharging into Lake Mead (fig. 1). The river sustains riparian habitat with diverse wildlife, including the endangered Virgin River chub and woundfin minnow.

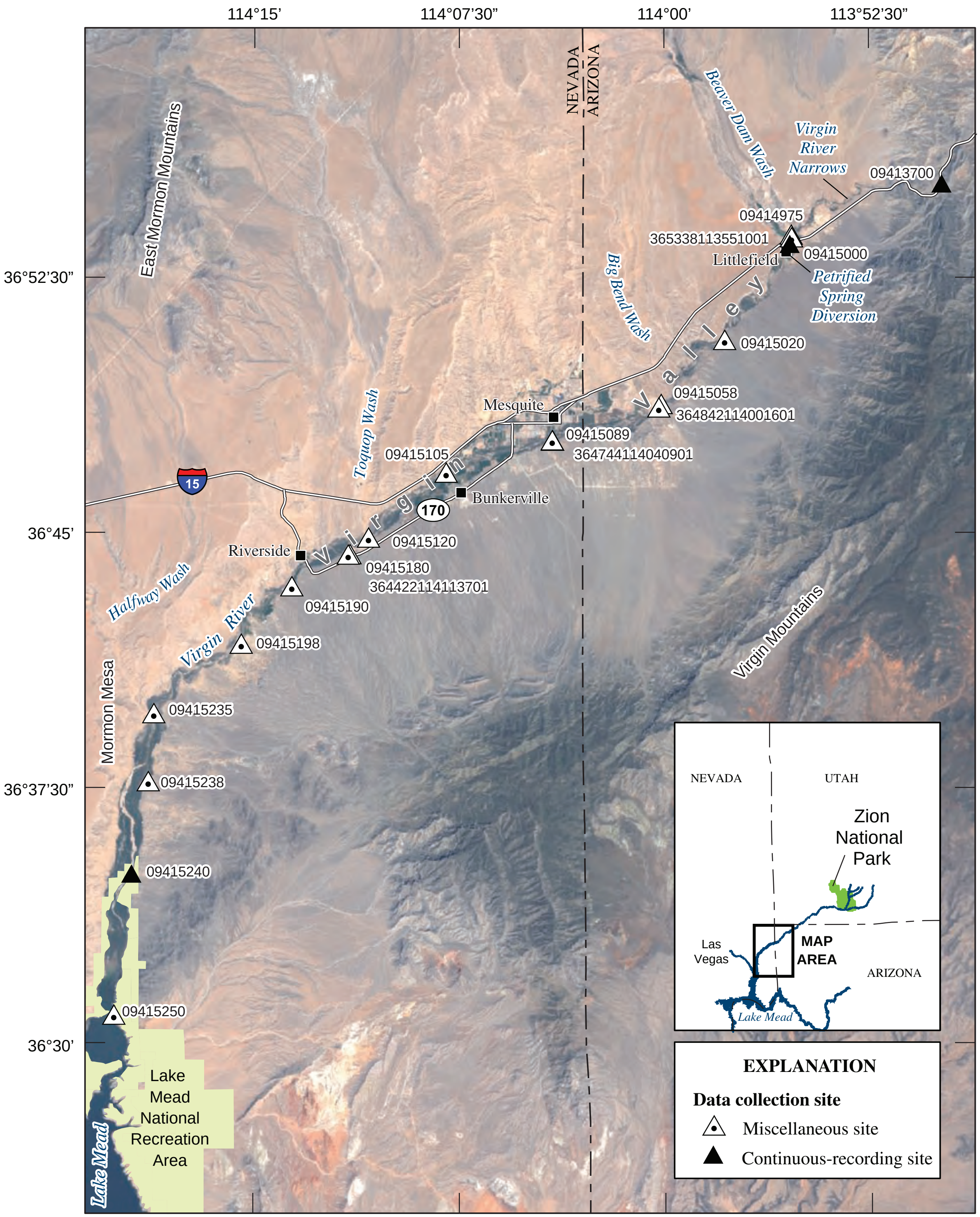
Rapid population growth in southern Nevada has increased demand for additional water supplies. Numerous applications for water rights are before the Nevada State Engineer to develop ground-water resources near the Virgin River. Resource managers have concerns about the effects of future ground-water withdrawals on riparian ecosystems and nearby spring-discharge areas adjacent to the river. Data currently are being collected to help evaluate effects of potential ground-water withdrawals on local and regional water availability, water rights, sensitive wildlife habitats, and other beneficial uses. As part of these efforts, this investigation was initiated to measure discharge, water temperature, and specific conductance along the Virgin River at selected locations between the Virgin River Narrows, Arizona, and Lake Mead, Nevada. Changes in streamflow along the lower Virgin River during periods of minimal surface inflow or evapotranspiration (ET) primarily are the result of exchanges with ground water. Detailed measurements of streamflow, water temperature, and specific conductance help quantify these exchanges.

Purpose and Scope

The purpose of this report is to present synoptic-dicharge, water-temperature, and specific-conductance data collected on February 12, 2003, at 19 selected sites along the lower Virgin River. The results of these measurements will help to identify reaches where gains or losses in discharge may be occurring. Synoptic measurements are those done concurrently over a broad area at a set time to give a “snap shot” of hydrologic conditions. These data were collected to help assess changes in stream discharge at points along a reach of the lower Virgin River during a period of minimal ET loss, surface-water inflow, and agricultural diversion. To help in the evaluation, synoptic-discharge data were measured at one tributary inflow and four diversions in the study area.

Description of Study Area

Dixon and Katzer (2002) document a study describing the hydrology and geology of the Virgin River. The current study was limited to the lower 50 mi of the Virgin River beginning at the U.S. Geological Survey (USGS) surface-water gage at Virgin River above the Narrows near Littlefield, Arizona (site 09413700; herein referred to as ‘Narrows gage’), and extending to Lake Mead (fig. 1). For purposes of this report, all references to the lower Virgin River indicate the study area.



Base from U.S. Geological Survey digital data, 1:100,000, 1979–1988. Universal Transverse Mercator projection, North American Datum of 1983, Zone 11. Natural-color composite image from Landsat 2000 thematic-mapper data.

0 10 MILES
0 10 KILOMETERS

Figure 1. Location of study area and synoptic-measurement sites. See table 1 for site information.

The lower Virgin River Basin is drained by a moderately steep meandering river that is bounded on the northwest and west by the East Mormon Mountains and Mormon Mesa, respectively, and on the east and south by the Virgin Mountains (fig. 1). Beaver Dam Wash flows into the lower Virgin River about 0.5 mi above Virgin River at Littlefield, Arizona (site 09415000; herein referred to as 'Littlefield gage'), and is the largest perennial tributary with an annual daily mean discharge of about 2.7 ft^3/s (USGS site 09414975). Discharge data are available at URL: <http://waterdata.usgs.gov/nv/nwis/>. Numerous small springs and seeps discharge directly into the river upstream of Littlefield, Arizona, but most are not measurable because of poor measuring conditions or restricted access. Three large ephemeral channels (Big Bend Wash, Toquop Wash, and Halfway Wash) drain into the Virgin River from the northwest and contribute surface discharge only during periods of intense precipitation.

The lower Virgin River channel typically consists of fine to coarse sands with rock riffles, consisting of cobbles and boulders, scattered throughout the reach. Dense vegetation is along the banks of the river and mainly consists of saltcedar (*Tamarix ramosissima*), cattail (*Typha latifolia*), and reeds (*Phragmites communis*).

The major populated areas within the lower Virgin Valley include the municipalities of Littlefield, Mesquite, Bunkerville, and Riverside (fig. 1). Water diverted from the river for these communities has changed from supporting agriculture to supporting residential and recreational developments primarily in Mesquite.

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The authors acknowledge the following agencies for their participation in this study: National Park Service; Virgin Valley Water District; Southern Nevada Water Authority; Nevada Division of Water Resources; Vidler Water Company, Inc.; CH2M HILL; and Interflow Hydrology, Inc. Special thanks goes to Michael Johnson of the Virgin Valley Water District who helped access the measuring sites and for logistical support during the course of the study.

Discharge Measurements

Discharge measurements were made at 19 sites in the study area. Of these sites, 14 were along the Virgin River, 1 site was at the confluence of Beaver Dam Wash with the Virgin River, and 4 sites were at agricultural diversions (table 1, fig. 1). At the 15 sites excluding the diversion, measurements were made hourly from 9:00 a.m. (PST) until 2:00 p.m. (PST) on February 12, 2003. Measurements at the four diversion sites were made at differing intervals between the same time periods. All discharge measurements were made with a current meter using standard methods of the USGS (Buchanan and Somers, 1969). Staff gages were installed at each site to monitor changes in stage.

Although river stage at most sites remained stable (within a few hundredths of a foot), discharge measurements at each selected site differed, on average, by about 8 percent with a maximum of 15 percent at one site. These differences reflect the inherent instability of sand-dominated channels as described by Rantz and others (1982). In spite of channel instability, each of the synoptic-discharge measurements made at the 14 sites along the Virgin River were rated good (within 5 percent of the actual discharge) based on estimates of standard error for each current-meter discharge measurement (Sauer and Meyer, 1992). Final discharge rates along the lower Virgin River were determined by computing a mean discharge from the synoptic measurements made at each site. The computed mean discharge and the maximum and minimum measured discharges are shown in figure 2 for each site.

Physical-Property Measurements

Water samples were collected from the 14 Virgin River sites and from Beaver Dam Wash at the beginning, midpoint, and end of the synoptic-measurement period. Water temperatures were measured at the beginning and end of the first discharge measurement and at the end of each subsequent discharge measurement. Water samples were analyzed for specific conductance at the USGS laboratory in Henderson, Nev. For this report, measurement errors for water temperature and specific conductance are based on criteria described in the USGS National Field Manual for the Collection of Water-Quality Data (U.S. Geological Survey, variously dated). Temperature measurements for liquid-in-glass thermometers should agree within 1 percent of full scale or 0.5°C, whichever is less. Specific conductance should agree within 3 percent at conductivity greater than 100 µS/cm. Mean values of water temperature (rounded to the nearest 0.5°C) and specific conductance (reported to three significant figures) were computed for each site and are listed in table 1. Plots of mean water-temperature and specific-conductance values for each site are shown in figure 3.

Table 1. Index to discharge and physical-property measurement sites from the Virgin River Narrows, Arizona, to Lake Mead, Nevada, February 12, 2003

[Note: Site elevation: elevation, in feet, above mean sea level (sea level in this report refers to the National Geodetic Vertical Datum of 1988); NAD83, North American Datum of 1983. Specific conductance: µS/cm at 25°C, microsiemens per centimeter at 25 degrees Celsius. Abbreviations: ft³/s, cubic feet per second; °C, degrees Celsius]

Site number (see fig. 1 for site location)	Site name	Coordinates NAD27		Distance downstream, in miles	Site elevation, in feet	Discharge, in ft^3/s			Water temperature[1], in °C	Specific conductance[2], water unfiltered, in µS/cm at 25°C
		Latitude	Longitude			Mean	Maximum	Minimum		
09413700[3]	Virgin River above the Narrows near Littlefield, Arizona	36°55'16"	113°49'52"	1.0	2,000	90.5	95.1	86.7	7.5	2,850
09414975	Beaver Dam Wash at Mouth near Beaver Dam, Arizona	36°53'40"	113°55'09"	8.5	1,790	6.37	6.60	6.08	8.0	721
365338113551001	Littlefield Diversion Channel	36°53'38"	113°55'10"	8.5	1,795	0.45	0.46	0.45		
09415000[3]	Virgin River at Littlefield, Arizona	36°53'30"	113°55'25"	9.0	1,765	158	160	154	13.0	2,980
09415020	Virgin River above Big Bend Wash near Littlefield, Arizona	36°50'41"	113°57'51"	14.0	1,700	148	151	144	13.0	2,960
09415058	Virgin River above Mesquite Diversion near Mesquite, Nevada	36°48'48"	114°00'11"	17.8	1,640	144	145	141	12.5	2,990
364842114001601	Mesquite Diversion	36°48'42"	114°00'16"	17.8	1,640	27.3	28.1	26.5		
09415089	Virgin River above Bunkerville Diversion near Mesquite, Nevada	36°47'44"	114°04'09"	22.1	1,560	128	134	124	12.5	3,000
364744114040901	Bunkerville Diversion	36°47'44"	114°04'09"	22.1	1,560	103	103	103		
09415105	Virgin River at Bunkerville, Nevada	36°46'47"	114°08'02"	26.3	1,510	128	132	121	13.0	3,150
09415120	Virgin River above Toquop Wash near Riverside, Nevada	36°44'52"	114°10'52"	30.0	1,460	120	127	110	11.0	3,260
09415180	Virgin River above Riverside Diversion near Riverside, Nevada	36°44'23"	114°11'33"	31.0	1,445	128	131	127	11.5	3,280
364422114113701	Riverside Diversion	36°44'22"	114°11'37"	31.0	1,445	32.1	35.1	30.8		
09415190	Virgin River at Riverside, Nevada	36°43'26"	114°13'40"	34.2	1,410	132	138	126	11.0	3,340
09415198	Virgin River below Meadowland Farms near Riverside, Nevada	36°41'45"	114°15'31"	37.4	1,360	135	140	132	11.0	3,390
09415235	Virgin River above Confluence with Halfway Wash near Riverside, Nevada	36°39'42"	114°18'42"	41.6	1,305	123	130	119	10.5	3,380
09415238	Virgin River 2.3 mi below Halfway Wash near Riverside, Nevada	36°37'42"	114°18'54"	44.0	1,280	124	127	118	10.5	3,380
09415240[3]	Virgin River near Overton, Nevada	36°34'59"	114°19'27"	47.4	1,230	116	120	110	9.0	3,430
09415250	Virgin River above Lake Mead near Overton, Nevada	36°30'50"	114°20'08"	52.8	1,150	133	137	129	9.0	3,410

[1]Mean value (rounded to nearest 0.5°C) .

[2]Mean value (rounded to three significant figures) .

[3]U.S. Geological Survey surface-water gaging station.

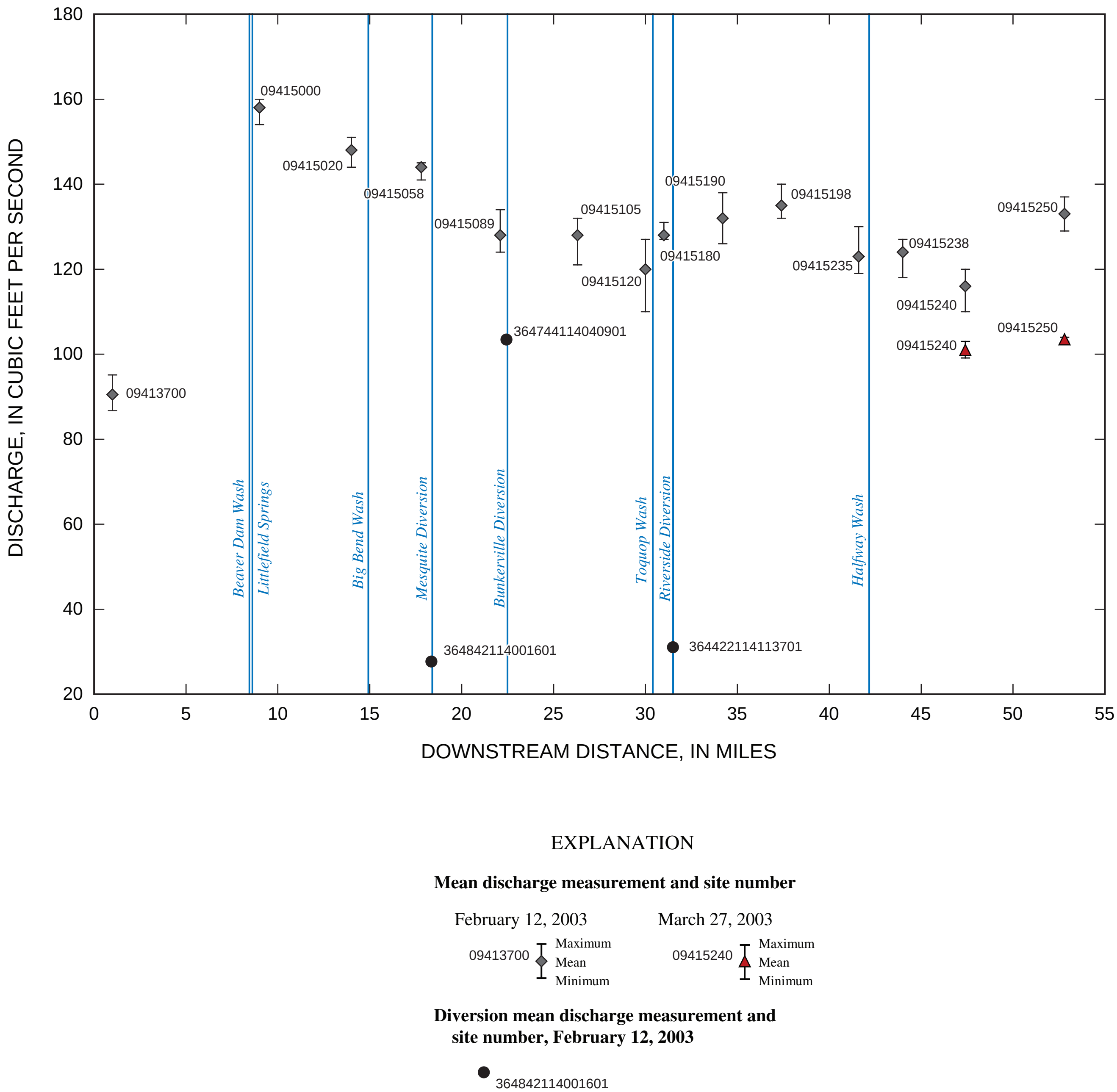

Figure 2. Computed mean, and maximum and minimum discharge measurements for selected sites from the Virgin River Narrows, Arizona, to Lake Mead, Nevada, February 12 and March 27, 2003. See table 1 for site information.

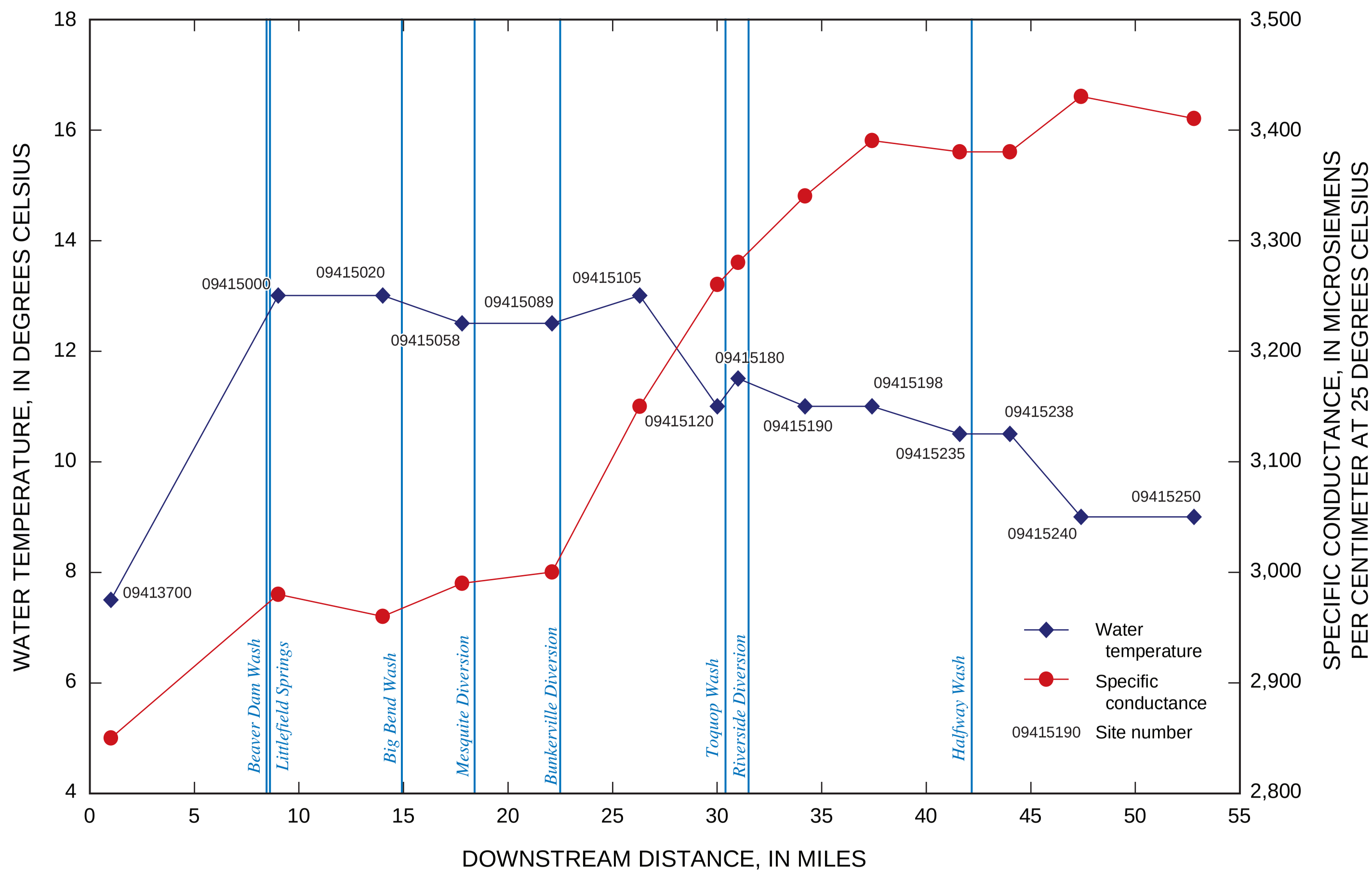

Figure 3. Mean water-temperature and specific-conductance measurements from selected sites from the Virgin River Narrows, Arizona, to Lake Mead, Nevada, February 12, 2003. See table 1 for site information.

Evaluation of the Lower Virgin River System

In order to identify losing or gaining reaches within the lower Virgin River, synoptic-measurement sites were selected based upon the location of (1) tributary inflow; (2) streamflow diversions; (3) potential ground-water inflow, including irrigation returns; and (4) accessible measuring sections. These measurements were made during a period of minimal ET and steady baseflow.

February was selected for the measurement period because ET rates are very low during this time of the year. The measured evaporative rate, determined for a dense area of saltcedar within the lower Virgin River, for February 12, 2003, was 0.2 millimeter per day (Guy DeMeo, U.S. Geological Survey, oral commun., July 12, 2005). Although this rate only represents a selected reach, it is considered the maximum rate within the lower Virgin River because all other areas contain less dense saltcedar growth. Based on this daily ET rate, instream losses resulting from ET are less than the error in discharge measurements.

During the course of the synoptic measurements, discharge measurements were made at four agricultural diversions within the lower Virgin River (Littlefield, Mesquite, Bunkerville, and Riverside). Another diversion, called the Petrified Spring diversion, diverts flow from a spring on the south bank between the I-15 bridge and the Littlefield gage (fig. 1). This diversion was inaccessible on February 12, 2003; however, the amount of water diverted was reported previously at 2–3 ft^3/s (Dixon and Katzer, 2002). Flow in the Littlefield diversion originates from Beaver Dam Wash (fig. 1) and is conveyed by a ditch along the north bank of the Virgin River to the town of Littlefield. Flow in the ditch on February 12, 2003, measured 0.45 ft^3/s, which amounts to less than 1 percent of the measured flow at the Littlefield gage. Measured discharge in the Mesquite, Bunkerville, and Riverside diversions during the synoptic-measurement period was 27.3, 103, and 32.1 ft^3/s, respectively. Although the Bunkerville diversion diverted nearly 80 percent of the diverted flow from the Virgin River, most of that water was observed returning back to the river through several concrete channels upstream of site 09415105 (Virgin River at Bunkerville; fig. 2).

Although the weather on February 12, 2003, was cool with light rain during the measurement period, near baseflow conditions were believed to be present throughout the entire lower Virgin River. Unit-value discharge hydrographs of three USGS continuous-recording gaging stations shown in figure 4 indicate that a small peak flow, either from precipitation or water released within the upper watershed, had entered the lower Virgin River during the early morning of February 11, 2003. The crest of the peak flow passed through the Narrows gage about 2:00 a.m. and subsequently passed through the Littlefield gage about 5:30 a.m. Although significantly attenuated, the crest passed through the Overton gage about 2:15 a.m. on February 12. Between the Littlefield and Overton gages, the travel velocity of this peak flow was estimated at 1.8 mi/h. Using this velocity, the peak flow would have taken about 3 hours to travel the 5.1 mi from the Overton gage to the last measurement site 09415250 (Virgin River above Lake Mead near Overton). Although the peak flow probably crested between 5:00 and 5:30 a.m. on February 12, discharge measurements taken at the lower site probably were made during the decline, but at higher stages of the peak flow. To confirm this assumption, another synoptic set of discharge measurements was made at the two lower sites during known baseflow conditions on March 27, 2003. Mean discharges computed for the gage near Overton and site 09415250 (Virgin River above Lake Mead near Overton) were 101 and 104 ft^3/s, respectively. The discharge rates at these two sites are considered similar because the difference between the two measurements falls well within the measurement error of 5 percent. The synoptic measurements made at site 09415250 (Virgin River above Lake Mead near Overton) on February 12, 2003, may have been influenced by the peak flow; therefore, they were not used for this evaluation.

In general, results of the synoptic-discharge and water-property measurements indicate three discernible trends. The first trend is a net increase in discharge, specific conductance, and water temperature between sites 09413700 (Narrows gage) and 09415000 (Littlefield gage). The second trend is a net decrease in discharge and water temperature between sites 09415000 (Littlefield gage) and 09415240 (Virgin River near Overton). The third trend is a net increase in specific conductance between sites 09415000 (Littlefield gage) and 09415240 (Virgin River near Overton).

The increase in discharge, water temperature, and specific conductance between sites 09413700 (Virgin River above the Narrows) and 09415000 (Virgin River at Littlefield) is well documented and primarily is the result of inflow from the Littlefield Springs (Dixon and Katzer, 2002). On February 12, 2003, the gains in discharge, water temperature, and specific conductance were 67.5 ft³/s, 5.5°C, and 130 µS/cm, respectively.

The net decreases in discharge and water temperature between sites 09415000 (Virgin River at Littlefield) and 09415240 (Virgin River near Overton) were 42 ft³/s and 4.0ºC, respectively. The net increase in specific conductance between the same sites was 450 µS/cm; however, the greatest change occurred between sites 09415089 (Virgin River above Bunkerville Diversion) and 09415198 (Virgin River below Meadowlands Farm; fig. 2) and seems to change downstream from the flow diversions. Though some minor perturbations exist within these trends, the general trends in discharge, water temperature, and specific conductance seem consistent with a river basin where surface water is diverted for agricultural and municipal purposes, and some diverted water is recycled back into the river through the shallow ground-water system downstream of the diversions.

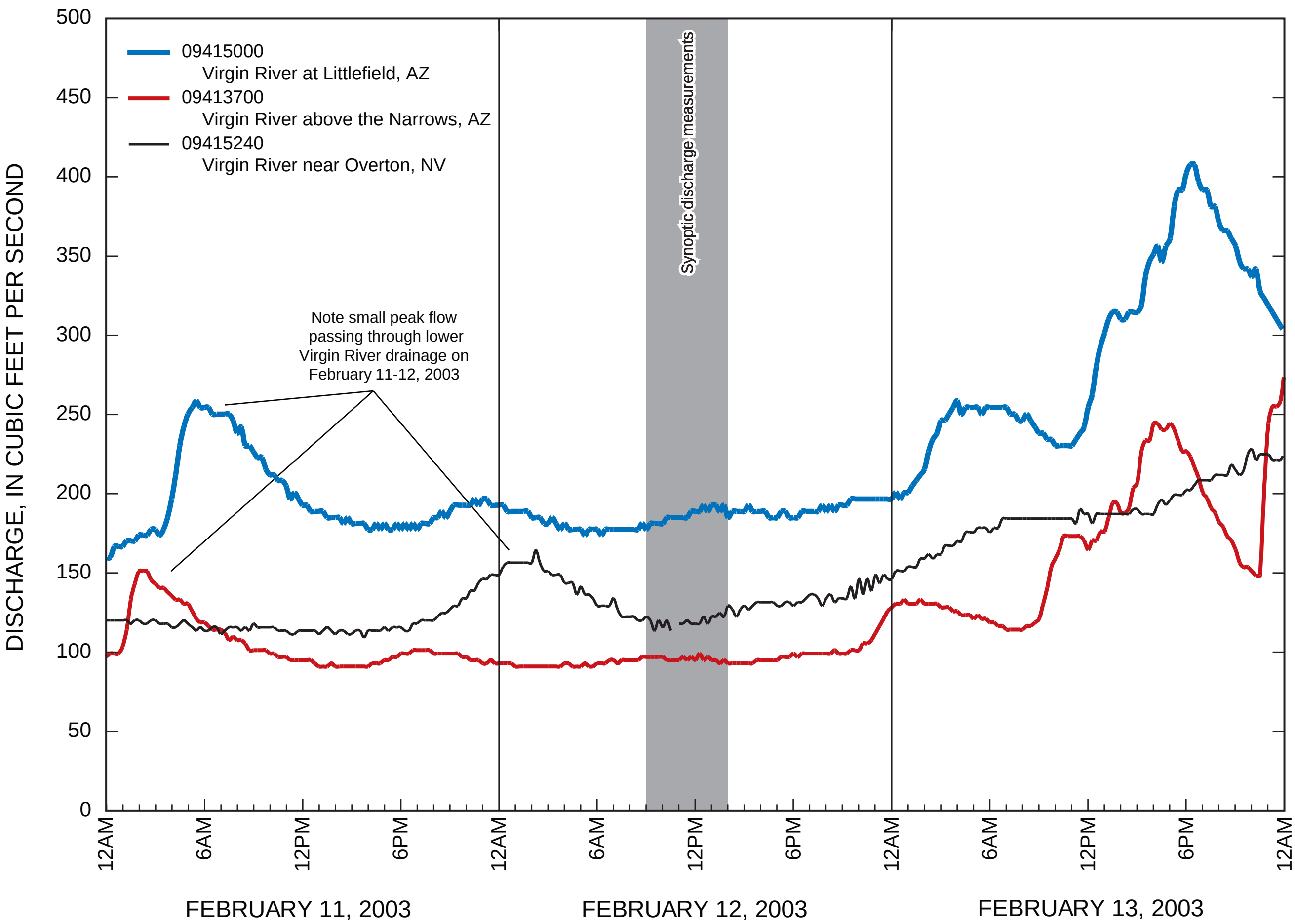

Figure 4. Unit discharges for U.S. Geological Survey surface-water gaging stations 09413700 Virgin River above the Narrows, Arizona; 09415000 Virgin River at Littlefield, Arizona; and 09415240 Virgin River near Overton, Nevada, February 11–13, 2003.

Summary

Synoptic-discharge measurements were made on February 12, 2003, along the lower Virgin River from the Narrows gage to Lake Mead, Nevada. Discharge, water-temperature, and specific-conductance data were collected at 19 sites to evaluate their spatial variability within the river during a period of low agricultural diversion and minimal ET rates. Five discharge measurements, on average, were made at each site within a time span of about 5 hours. A mean discharge was used to represent the discharge rates for each measurement site. The lowest mean discharge, 90.5 ft^3/s, was measured at the Narrows gage. The highest mean discharge, 158 ft^3/s, was measured at the Littlefield gage. Mean discharges between the Littlefield gage and Lake Mead ranged from 116 to 148 ft^3/s. An increase in discharge between the two lower sites (09415240 and 09415250) was attributed primarily to an increase in streamflow and not from ground-water inflow.

The lowest average water temperature was 7.5°C at the Narrows gage. The highest average water temperature was 13°C at the Littlefield gage and at sites 09415020 and 09415105. Specific-conductance measurements ranged from 2,850 µS/cm at the Narrows gage to 3,430 µS/cm at site 09415250.

Between the Narrows and Littlefield gages, mean discharge, mean water temperature, and specific conductance indicated net increases of 67.5 ft^3/s, 5.5°C, and 130 µS/cm, respectively. Between the Littlefield gage and site 09415250, mean discharge and water temperature indicated a net decrease of 42 ft^3/s and 4.0°C, respectively, whereas specific conductance indicated a net increase of 450 µS/cm.

The general trends in discharge, water temperature, and specific conductance on February 12, 2003, in the lower Virgin River from the Virgin River Narrows, Arizona, to Lake Mead, Nevada, seem consistent with a river basin where surface water is diverted for agricultural and municipal purposes, and some diverted water is recycled back into the river through the shallow ground-water system downstream of the diversions.

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