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Discharge, Suspended Sediment, Bedload, and Water Quality in Clear Creek, Western Nevada, Water Years 2010–12

Scientific Investigations Report 2015–5124

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

Cover: Photograph showing hydrologic technician, Joseph Joyner, hiking to headwater sample site, Clear Creek above Highway 50 near Spooner Summit, Nevada (USGS streamgage 10310485). (Photograph taken by Daniel Riddle, U.S. Geological Survey.)

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SALLY JEWELL, Secretary

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Conversion Factors

Inch/Pound to International System of Units

Multiply	By	To obtain
	Length	
inch	0.0254	meter (m)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year (m^3/yr)
acre-foot per year (acre-ft/yr)	0.001233	cubic hectometer per year (hm^3/yr)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
	Mass	
ton per day (ton/d)	0.9072	metric ton per day
ton per day (ton/d)	0.9072	megagram per day (Mg/d)
ton per year (ton/yr)	0.9072	megagram per year (Mg/yr)
ton per year (ton/yr)	0.9072	metric ton per year
ton per square mile per year [(ton/mi^2)/yr]	0.3502	ton per square kilometer per year [(ton/km^2)/yr]
	Hydraulic gradient	
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

°F=(1.8×°C)+32.

Supplemental Information

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

Concentrations of chemical constituents in water are given in either milligrams per liter (mg/L) or micrograms per liter (µg/L).

Datums

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929.

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

Altitude, as used in this report, refers to distance above the vertical datum.

Discharge, Suspended Sediment, Bedload, and Water Quality in Clear Creek, Western Nevada, Water Years 2010–12

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Abstract

Clear Creek is a small stream that drains the eastern Sierra Nevada near Lake Tahoe, flows roughly parallel to the U.S. Highway 50 corridor, and discharges to the Carson River near Carson City, Nevada. Historical and ongoing development in the drainage basin is thought to be affecting Clear Creek and its sediment-transport characteristics. A baseline study from water years 2004–07 collected and evaluated data at three Clear Creek sampling sites. These data included discharge, selected water-quality parameters, and suspended-sediment concentrations, loads, and yields. This study builds on what was learned from the baseline study in water years 2004–07 and serves as a continuation of the data collection and analyses of the Clear Creek discharge regime and associated water-quality and sediment concentrations and loads during water years 2010–12.

During this study, total annual sediment loads ranged from 355 tons per year in 2010 to 1,768 tons per year in 2011 and were significantly lower than the previous study (water years 2004–07). Bedload represented between 29 and 38 percent of total sediment load in water years 2010–12, and between 72 and 90 percent of the total sediment load in water years 2004–07, which indicates a decrease in bedload between study periods. Annual suspended-sediment loads in water years 2010–12 indicated no significant change from water years 2004–07. Mean daily discharge was significantly lower in water years 2010–12 than in waters years 2004–07 and may be the reason for the decrease in bedload that resulted in a lower total sediment load.

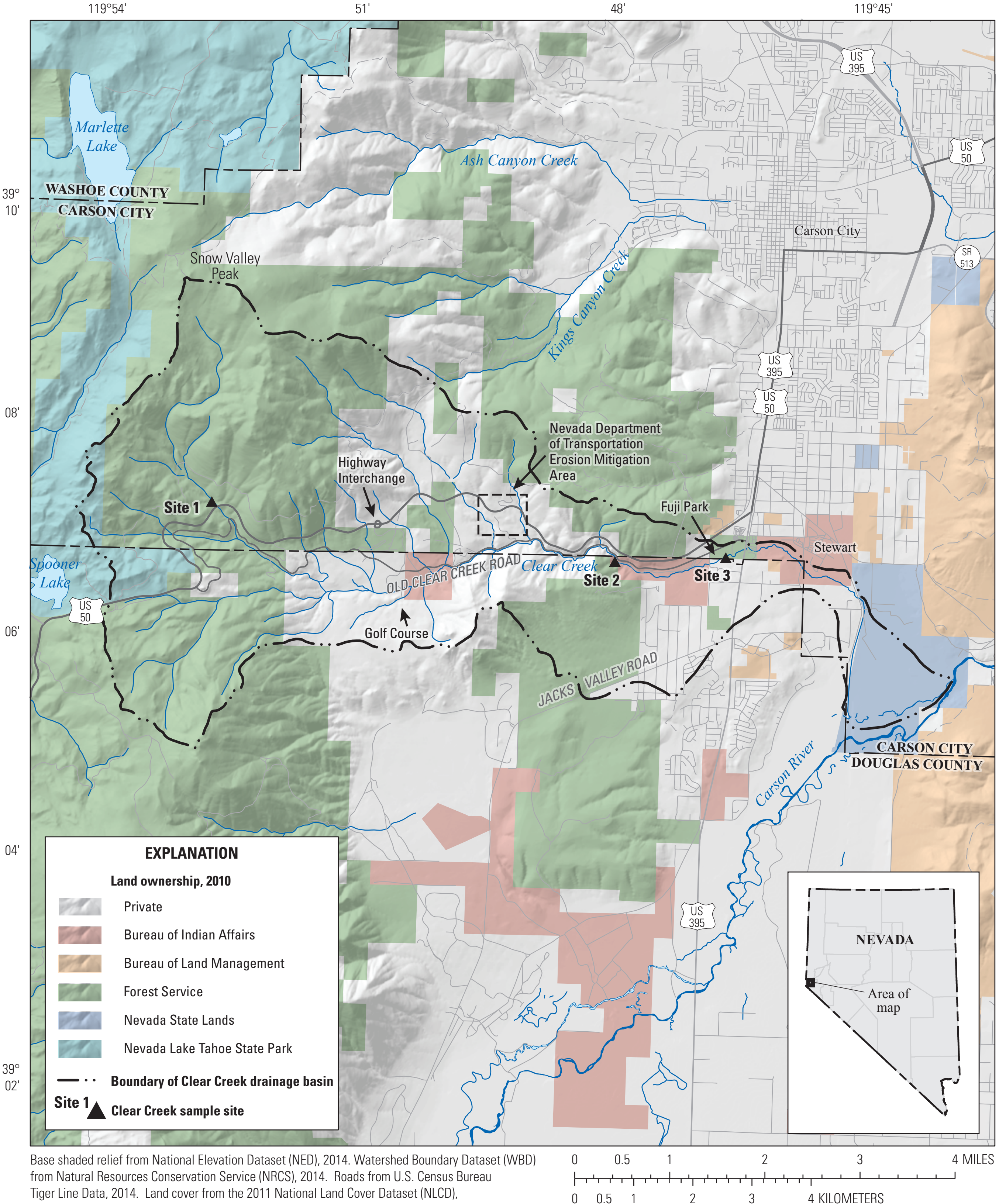
Introduction

The Clear Creek drainage basin in Eagle Valley lies along the eastern front of the Sierra Nevada near Carson City, Nevada (fig. 1). The upper portions of the drainage basin border the Lake Tahoe Basin. Clear Creek is a perennial alpine stream that has its headwaters near Snow Valley Peak (altitude 9,219 ft), with three main perennial branches and several small intermittent tributaries originating from springs and seeps. Clear Creek generally flows eastward along its approximate 12 mi length and discharges to the Carson River at an altitude of about 4,600 ft near the small community of Stewart, Nevada (fig. 1).

Clear Creek, for much of its upper reach, typifies the small, clear, cool streams of the Sierra Nevada as it winds its way through predominantly forested, shrub/scrub lands and occasional grassland areas (fig. 2; Homer and others, 2015). Forest fires, extreme precipitation events, and human activities have led to channel erosion and incision in the mid-portion of the drainage basin and sediment deposition in the lower portions of the drainage basin. Construction of large commercial buildings and parking lots adjacent to and near the creek's lower reaches also may be affecting stream-water quality and sediment yield. Other potential anthropogenic influences on Clear Creek water quality and sediment loading may include the U.S. Highway 50 interchange (completed August 2007), a golf course (completed in 2008), and a residential community (under construction) in the mid-portion of the drainage basin.

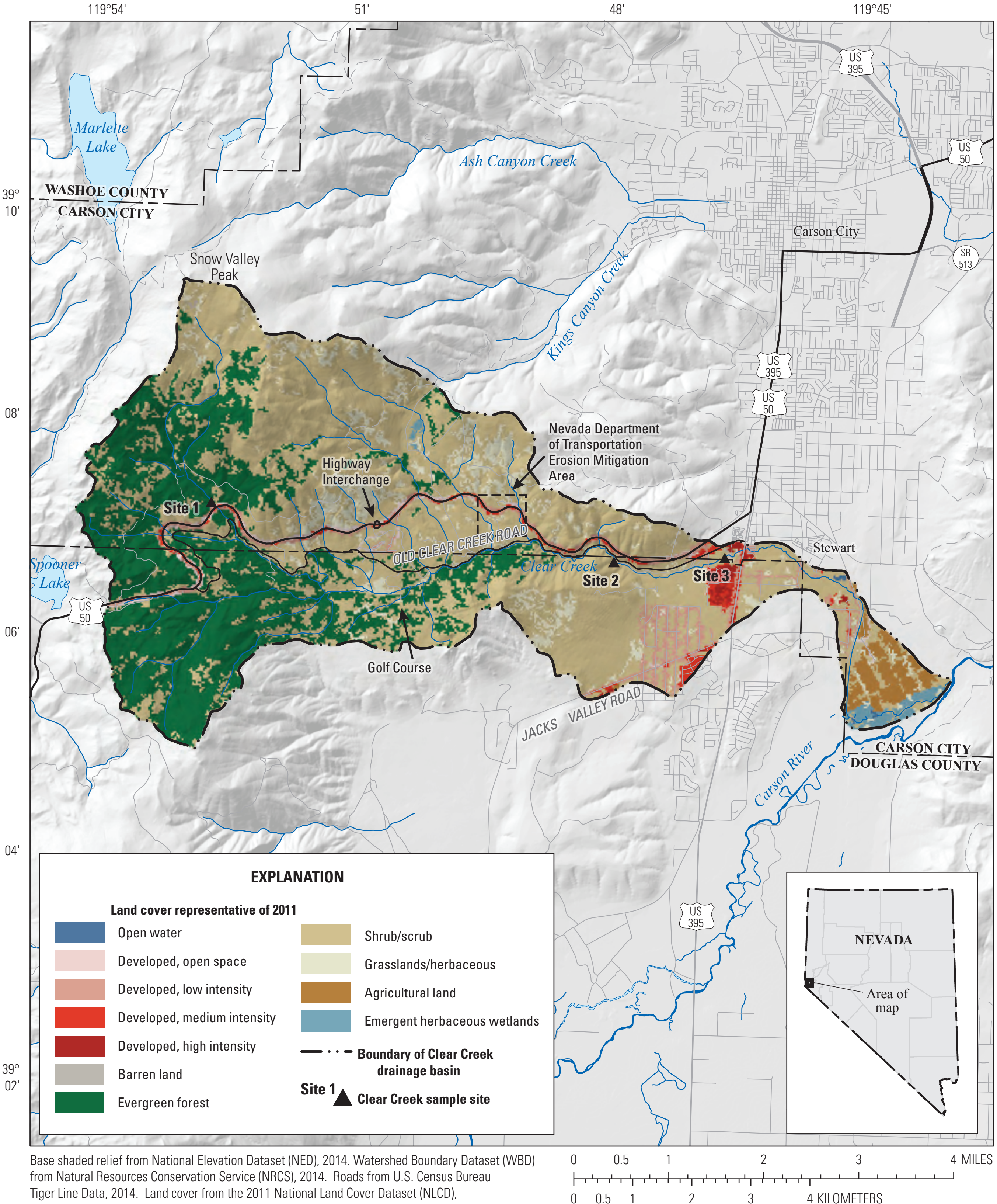
In addition to urbanization, another factor potentially affecting Clear Creek water quality is the application of road salt to roads in the drainage basin. To provide winter access to private, State, Federal, and Tribal lands in the basin, salt is applied to Old Clear Creek Road (fig. 1) and, in places, the road is in close proximity to the stream. In the lower reaches of Clear Creek, the stream may be affected by urban and highway runoff, agricultural return flows, and seepage from septic-tank systems.

In February 2004, the Nevada Division of Environmental Protection (NDEP) issued a "National Pollutant Discharge Elimination System" permit to the Nevada Department of Transportation (NDOT) for pollutants discharged into the municipal storm water sewer system (Nevada Department of Transportation, 2005). In response, NDOT developed the Clear Creek Storm Water Management Program in 2005 to meet the requirements of the permit, which were to reduce the discharge of pollutants to the storm water drainage systems associated with highways and highway-related properties, facilities, and activities operated by NDOT in the Clear Creek drainage basin.



Base shaded relief from National Elevation Dataset (NED), 2014. Watershed Boundary Dataset (WBD) from Natural Resources Conservation Service (NRCS), 2014. Roads from U.S. Census Bureau Tiger Line Data, 2014. Land cover from the 2011 National Land Cover Dataset (NLCD), U.S Geological Survey, 2015. Universal Transverse Mercator projection, Zone 11 North North American Datum of 1983

Figure 1. Clear Creek drainage basin, land ownership, and sampling sites near Carson City, western Nevada. Drainage basin boundary from U.S. Geological Survey and U.S. Department of Agriculture, Natural Resources Conservation Service (2013).



Base shaded relief from National Elevation Dataset (NED), 2014. Watershed Boundary Dataset (WBD) from Natural Resources Conservation Service (NRCS), 2014. Roads from U.S. Census Bureau Tiger Line Data, 2014. Land cover from the 2011 National Land Cover Dataset (NLCD), U.S Geological Survey, 2015. Universal Transverse Mercator projection, Zone 11 North North American Datum of 1983

Figure 2. Generalized land cover in the Clear Creek drainage basin, Carson City and Douglas County, western Nevada. Drainage basin boundary from U.S. Geological Survey and U.S. Department of Agriculture, Natural Resources Conservation Service (2013).

As part of NDOT's Storm Water Management Program, the U.S. Geological Survey (USGS) began a cooperative study with NDOT to assess baseline conditions of general water quality and sediment loading within the Clear Creek drainage basin. Water-quality and sediment data were collected during water years[1] 2004–07 (initial phase of this cooperative study) and results reported by Seiler and Wood (2009). This report provides additional information on sediment and water-quality characteristics in Clear Creek during 2010–12.

Purpose and Scope

Discharge, sediment, and water-quality data were collected during 2010–12 at three sites in the Clear Creek drainage basin (fig. 1) in collaboration with NDOT. The objectives of this study were to build on previous monitoring and investigative studies in the Clear Creek drainage basin by evaluating (1) long-term stream discharge, (2) long-term sediment transport properties and potential changes in total sediment load over time, and (3) concentrations of selected chemical constituents in Clear Creek.

Previous Investigations

Numerous studies have collected data in the Clear Creek drainage basin. Glancy and Katzer (1976), in their appraisal of the Carson River Basin, reported the 1948–62 Clear Creek annual mean discharge was 5.42 ft^3/s. Piper (1969) studied runoff in the Carson Valley area and determined that runoff was greater at higher elevations and decreased with increasing distance from the Sierra Nevada. Discharge data collected in the Clear Creek drainage basin by the USGS were published in the annual data report (U.S. Geological Survey, 2012a) and are available from the USGS National Water Information System. The long-term annual mean discharge at the streamgage on Clear Creek near Carson City (fig. 1, site 2, USGS streamgage 10310500) is 5.31 ft^3/s (period of record 1949–62 and 1990–2012).

Several studies have focused on sediment movement in the Clear Creek drainage basin, including Brown and Skau (1977), Fisher (1978), Stevenson (1989), Fritchel (2003), and PBS&J (2003). PBS&J (2003) found that sediment transported in Clear Creek could reach the Carson River during major flood events. Seiler and Wood (2009) determined that, when discharge was high enough to transport bedload, it was primarily composed of sand and gravel (80 percent sand) and that bedload contributed 6–92 percent (average of 73 percent) of the total sediment load in the creek (Seiler and Wood, 2009, p. 26). These results are similar to those found by Fisher (1978), where bedload contributed 78 percent of the total sediment load. Seiler and Wood (2009) reported suspended-sediment concentrations of 2–1,150 mg/L in 2004–07, with the highest concentrations occurring during isolated storm runoff events and snowmelt runoff in the spring. Generally, water quality in Clear Creek met all U.S. Environmental Protection Agency primary and secondary drinking-water standards, with the exception of turbidity, which exceeded the 5 Nephelometric Turbidity Units (NTU) standard during spring runoff and storm events.

Description of Study Area

The Clear Creek study area covers almost 19.8 mi^2 and drains the eastern slope of the Sierra Nevada in the Eagle Valley hydrographic area[2] of the Carson River drainage basin (fig. 1). This study area is nearly 2 mi^2 larger than what Seiler and Wood (2009, p. 3) reported because the Clear Creek drainage basin boundary was delineated during this study using an updated watershed boundary dataset (U.S. Geological Survey and U.S. Department of Agriculture, Natural Resources Conservation Service, 2013). The altitudes in the study area ranges from about 9,200 ft in the headwaters to 4,765 ft at Fuji Park (near site 3). After leaving Fuji Park, Clear Creek flows an additional 2.5 mi to its confluence with the Carson River in southern Carson City (fig. 1). The average main channel slope is about 1,000 ft/mi at the high-elevation headwaters area, about 308 ft/mi (6 percent slope) in the 1-mile reach upstream of site 2, and about 58 ft/mi (1 percent slope) where Clear Creek enters Eagle Valley (Seiler and Wood, 2009, p. 17).

Seiler and Wood (2009, p. 3–12) describe the climate, land use, vegetation cover, road network, geology, and soils in the study area. To summarize, the study area lies in the rain

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[1] A water year is the period from October 1 to September 30; it is designated by the year in which it ends. Water year is used almost exclusively throughout this report. In order to reduce confusion between calendar years and water years in this report, all reference to years and periods is to water years unless specifically referred to as calendar year.

[2] Formal hydrographic areas in Nevada were delineated systematically by the U.S. Geological Survey and Nevada Division of Water Resources in the late 1960s for scientific and administrative purposes (Cardinalli and others, 1968; Rush, 1968). The official hydrographic-area names, numbers, and geographic boundaries continue to be used in U.S. Geological Survey information products and Nevada Division of Water Resources administrative activities.

shadow of the Sierra Nevada and precipitation falls primarily as winter snow; however, winter and/or summer thunderstorms also can generate considerable precipitation. Jeffrey pine (*Pinus jeffreyi*) and white fir (*Abies concolor*) are dominant on the high east- and north-facing slopes. Manzanita (of genus *Arctostaphylos*) and sagebrush (*Artemisia tridentate*) prevail on the south-facing slopes and low altitudes. The Clear Creek watershed drainage basin is composed mostly of Mesozoic granite of the Sierra Nevada batholith (Moore, 1969; Stewart, 1980; Seiler and Wood, 2009), with small areas of metavolcanic and metamorphic rocks in the northwestern part of the basin (Seiler and Wood, 2009, fig. 8). Alluvial deposits, derived from the adjacent mountains, dominate the geology from where the creek emerges from the canyon to its confluence with the Carson River (Moore, 1969).

The study area is mostly undeveloped; however, commercial development has occurred in the eastern low altitudes area since 2003 (Seiler and Wood, 2009, fig. 3). Developments in the study area, which disrupt the natural flow of surface water, have included the road network, several residential areas, a golf course, and a commercial development (fig. 2). The road network, U.S. Highway 50, Old Clear Creek Road, and access roads, have been major contributors to erosion processes (Stevenson, 1989; Forman, 2003). Large road cuts and embankments formed steep slopes susceptible to rill erosion and landslides. Discharge from culverts associated with the road development also have caused gullies. NDOT, as part of the Storm Water Management Program, has identified areas most susceptible to erosion and has begun implementing mitigation efforts (see erosion mitigation area in fig. 2; Christopher Holman, Nevada Department of Transportation, written commun., February 9, 2015).

Surface-Water Hydrology

Discharge was measured at the same three sites in the Clear Creek drainage basin (fig. 1, table 1) as measured by Seiler and Wood (2009). Site 1 represents the 2.4 mi^2 forested and undeveloped headwaters area of Clear Creek upstream of U.S. Highway 50 (fig. 2). Site 2 represents the reach of Clear Creek that extends 5.7 river miles downstream of site 1 and an additional 13.0 mi^2 of drainage area (15.4 mi^2 cumulative) consisting of shrub/scrub community vegetation, forest, dense riparian vegetation, and low-density residential areas (fig. 2). Just upstream of the streamgage (site 2), Clear Creek enters a narrow granite bedrock canyon. Site 3 represents the reach of Clear Creek that extends 1.4 river miles downstream of site 2 and an additional 2.7 mi^2 drainage area (18.1 mi^2 cumulative) consisting of similar land cover as site 2, with the addition of some urbanized areas (fig. 2). After exiting the narrow granite bedrock canyon at site 2, Clear Creek proceeds across an alluvial fan and then to Fuji Park and U.S. Highway 395. More detailed site descriptions are provided in Seiler and Wood (2009).

At sites 1 and 3, only discrete discharge measurements were made during sediment or water-quality sampling. The site 2 streamgage, Clear Creek near Carson City, Nevada (USGS streamgage 10310500; altitude 5,000 ft) was a continuous recording streamgage from 1948 to 1962 and from 1989 to 2012. From 1963 to 1988, the streamgage was a crest-stage gage and only peak discharges were determined. When the streamgage was operating continuously, stage was recorded at 15-minute intervals and then 15-minute discharges were computed (Rantz, 1982a, 1982b). Daily mean discharge was computed from the 15-minute discharges. During periods of ice effect[3] or instrument malfunction, daily mean discharges were estimated. Discrete discharge measurements were taken at site 2 during sediment and water-quality sampling events throughout the study period (2010–12). All summary discharge data for the three sites have been published in USGS annual data reports (U.S. Geological Survey, 2010, 2011, 2012b).

Table 1. Description of discharge and sampling sites on Clear Creek, western Nevada.

[Latitude and longitude are in degrees, minutes, seconds, North American Datum of 1983 (NAD 83). **Site altitude** is in feet above National Geodetic Vertical Datum of 1929 (NGVD 29)]

Site No. (see fig. 1)	Site name	USGS station ID	Latitude	Longitude	Drainage area (square miles)	Site altitude
1	Clear Creek above Highway 50, near Spooner Summit	10310485	39º07'14"	119º52'35"	2.4	6,620
2	Clear Creek near Carson City	10310500	39º06'48"	119º47'50"	15.5	5,000
3	Clear Creek at Fuji Park, at Carson City	10310518	39º06'52"	119º46'32"	17.8	4,765

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[3] "Ice effect," as described by Rantz (1982b, p. 360), is when the formation of ice in stream channels affects the stage-discharge relation by causing backwater that varies in effect with the quantity and nature of the ice, as well as with the discharge.

Annual mean discharge at site 2 has varied throughout the periods of continuous gaging (1949–62 and 1990–2012) (fig. 3). Discharge data from 2010 to 2012 were added to the long-term dataset as part of this study, resulting in a long-term mean annual discharge of 5.31 ft^3/s at site 2. The mean annual discharge at site 2 during this study was 3.25 ft^3/s in 2010, 7.13 ft^3/s in 2011, and 3.99 ft^3/s in 2012 (fig. 3). The maximum mean annual discharge for the creek over the entire period of record was 13.4 ft^3/s in 1997, and the minimum was 2.09 ft^3/s in 1992. The variation in mean annual discharge is caused primarily by the annual variation of snowpack in the drainage basin; however, significant rain-on-snow events can occur, such as in 1997. During the previous study (2004–07), only 2006 mean annual discharge (8.64 ft^3/s) was greater than the long-term mean annual discharge; during the current study (2010–12), only 2011 mean annual discharge (7.13 ft^3/s) was greater than the long-term mean annual discharge (fig. 3).

Mean monthly discharge at site 2 for the periods of record (March 1948–September 1962 and February 1989–September 2012) ranged from 0.67 to 36.3 ft^3/s (fig. 4). Mean monthly discharge statistics were computed based on months for which complete records of discharge were available. Generally, the maximum median mean-monthly discharge was in April, while the minimum median discharge was in August and September. Discharge in water year 2010 was less than average because nearly all monthly mean discharges were less than the median mean monthly discharge for the period of record (fig. 4). During water year 2011, October–February mean monthly discharges generally were less than the median mean monthly discharges for the period of record; however, high streamflow resulting from an above-normal snowpack increased the March–September mean monthly discharge to greater than the 75th percentile for mean monthly discharges for the period of record (fig. 4). October and November in water year 2012 continued to exhibit greater mean monthly discharge; however, from April through September 2012, mean monthly discharge receded to less than the mean monthly discharge for the period of record (fig. 4). The greatest January outlier corresponds to the 1997 rain-on-snow event, and the greatest April and May outliers both correspond to a 1952 event (fig. 4).

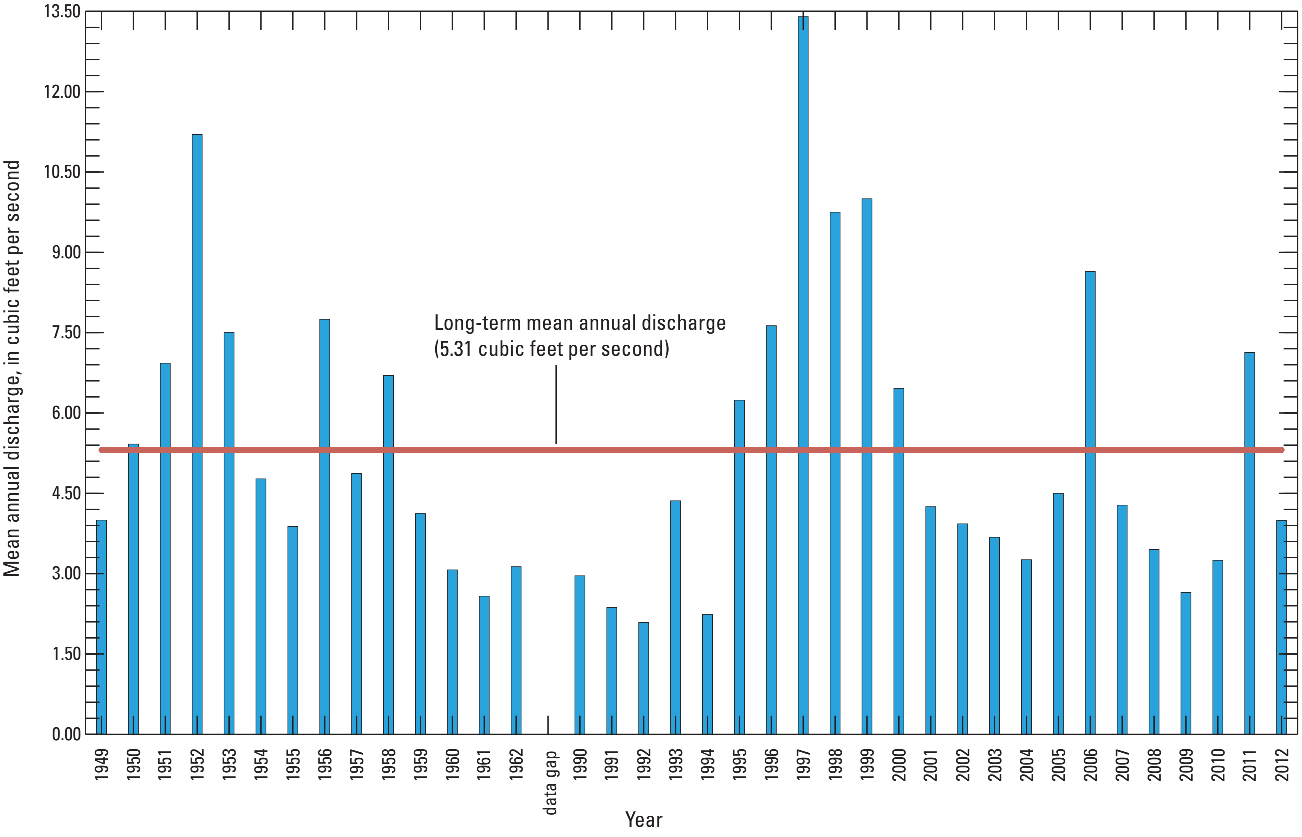

Figure 3. Mean annual discharge for periods of record at site 2, Clear Creek near Carson City, Nevada (USGS streamgage 10310500), water years 1949–62 and 1990–2012.

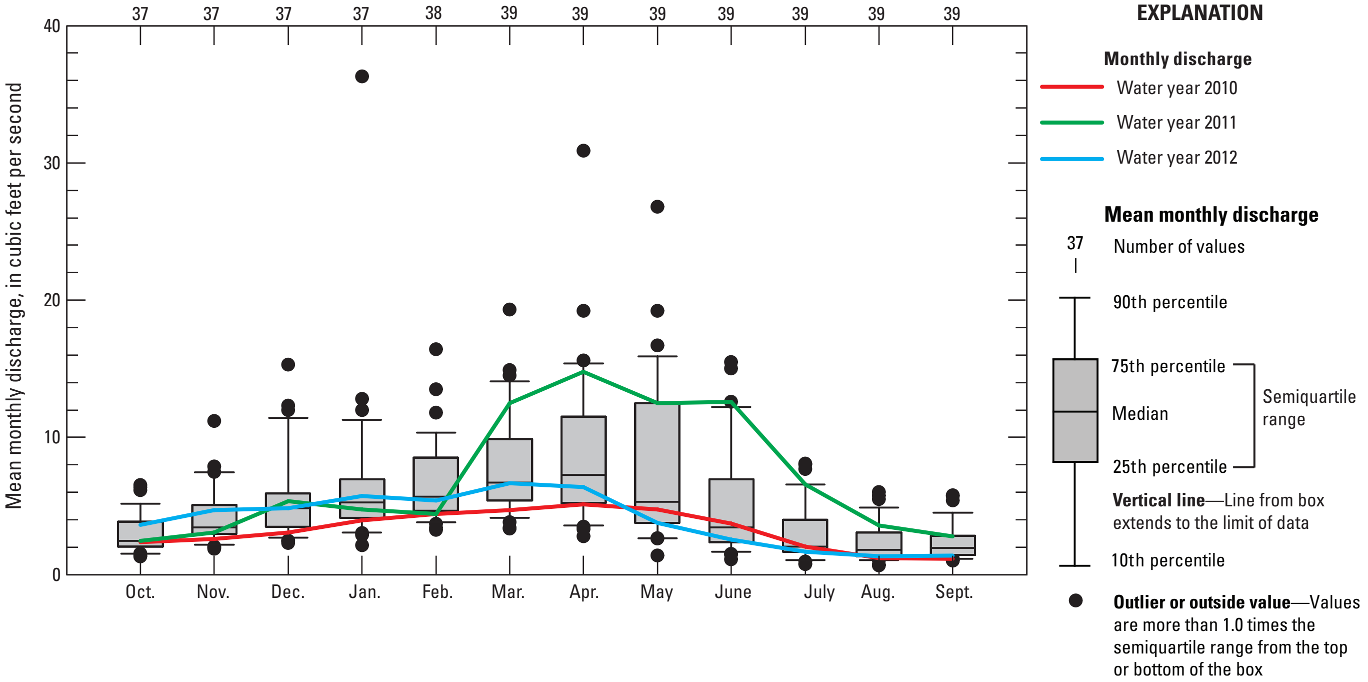

Figure 4. Mean monthly discharge for periods of record, water years 1949–62 and 1990–2012 and monthly discharge for water years 2010–12, at site 2, Clear Creek near Carson City, western Nevada (USGS streamgage 10310500).

Daily mean discharge of Clear Creek ranged from 0.87 to 45 ft³/s during 2010–12 (figs. 5*A*–5*C*). Relatively low discharge conditions occurred in Clear Creek during 2010 and 2012 (figs. 5*A* and 5*C*). In 2011, above-normal snowpack led to greater snowmelt, increasing discharge in Clear Creek to above normal throughout the spring and into the autumn (fig. 5*B*). Daily mean discharge of Clear Creek is important because it is used to compute annual sediment loads.

For the purposes of this study, flow-duration curves were created for stream discharge measured at site 2 for three periods of record to better understand any differences in sediment transport dynamics in the system. Figure 6 shows, for example, that 30 percent of the mean daily discharges in Clear Creek are likely to equal or exceed 6 ft³/s. The long-term discharge dataset was used to characterize low, moderate, and high discharge conditions for Clear Creek (fig. 6, upper x-axis). For the purposes of this evaluation,

- low discharge conditions were defined as mean daily discharges less than the 25th percentile (about 2.4 ft³/s);
- moderate discharge conditions were defined as mean daily discharges representing the 25th and 75th percentiles of mean daily discharges, respectively (about 2.4 to 6.7 ft³/s); and,
- high discharge conditions were defined as mean daily discharges exceeding the 75th percentile (6.7 ft³/s).

The actual stream-discharge values associated with each percentile of the dataset may change over time as additional discharge data become available and are incorporated into the long-term dataset. When using the discharge characterizations, it should be understood that the 25th discharge percentile (about 2.4 ft³/s) is exceeded 75 percent of the time (fig. 6).

A visual comparison of mean daily discharge for 2004–07 and 2010–12 to the long-term record (1949–2003) shows that, with the exception of the extreme high-discharge and low-discharge endpoints, discharge characteristics among the three periods of record were similar, as evidenced by the mean daily discharges between the 2nd (19 ft³/s) and 91st (1.5 ft³/s) percentiles (fig. 6). During 2004–07, there were more mean daily discharges greater than 20 ft³/s, which likely resulted from the 2006 flood. Departures from the long-term record on the low-discharge end (greater than 95th percentile) represent small increments of discharge relative to departures on the high-discharge end (less than 1st percentile). When compared to the long-term dataset, mean daily discharges for both the previous and current datasets were within the range of flows historically observed for the creek.

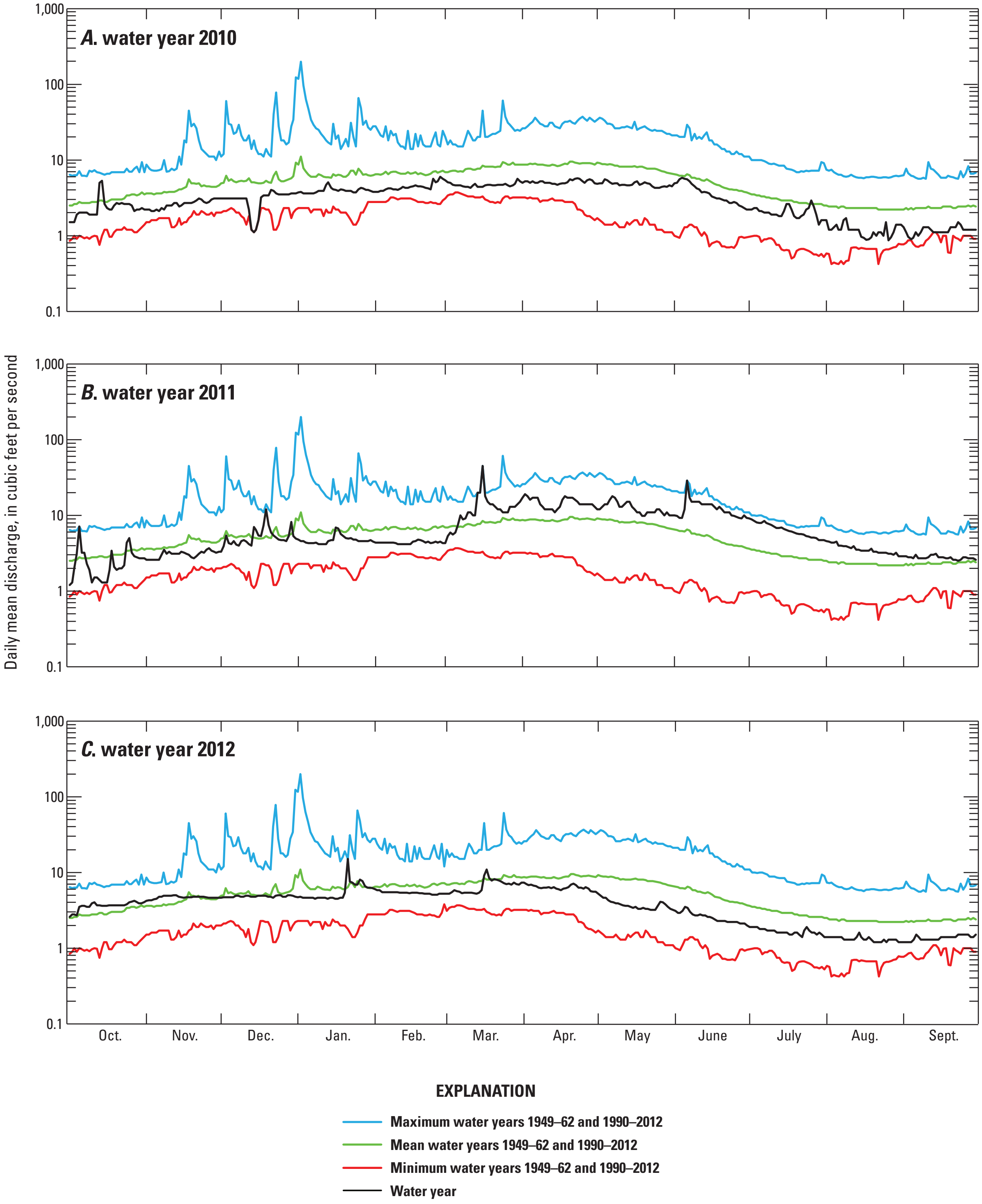

Figure 5. Daily mean discharges for (*A*) water year 2010, (*B*) water year 2011, and (*C*) water year 2012 and periods of record for site 2, Clear Creek near Carson City, western Nevada (USGS streamgage 10310500).

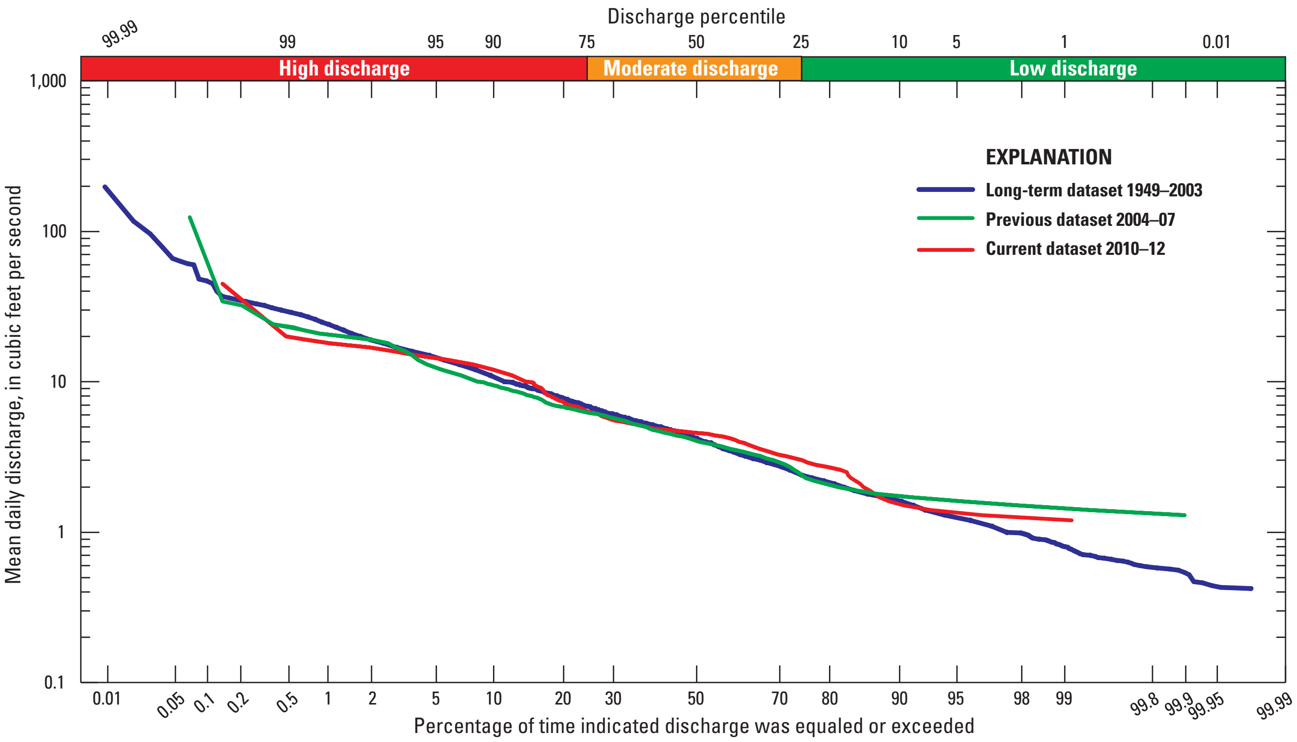

Figure 6. Flow duration at site 2, Clear Creek near Carson City, western Nevada (USGS streamgage 10310500), water years 1949–2003 (long-term dataset), 2004–07 (previous dataset), and 2010–12 (current dataset).

The shape (slope) of a flow-duration curve can be used to determine hydrologic and geologic characteristics of a drainage area (Searcy, 1959, p. 22). Curves that exhibit a relatively flat slope at the low end (low discharge) generally are indicative of a snowmelt-dominated drainage basin (high discharges are distributed over fairly long time periods), as is the case in Clear Creek. The sudden changes in slope seen in the previous dataset (2004–07; discharge greater than 22 ft^3/s) and in the current dataset (2010–12; discharge greater than about 10 ft^3/s) are likely caused by the 2006 storm event and the 2011 spring runoff, which followed an above average snowpack (see section, “Annual Peak Discharge and Floods”), which can be considered to be more episodic than distributed events. Maurer and others (2008) also found similarly shaped duration curves in the Carson River Basin.

Annual Peak Discharge and Floods

The annual peak discharge of a stream is the maximum instantaneous discharge recorded during a given water year. Peak discharge varies from water year to water year depending on the amount of snow and the water content of the snowpack in the drainage basin, the melt rate, and occurrences of rain-on-snow or summer thunderstorm events. At site 2, 55 annual peak discharges were measured during 1948–78 and 1989–2012 and greatly varied, ranging from 5 to 266 ft^3/s (fig. 7). The minimum annual peak discharge was 5 ft^3/s in 1976 and 1977. The maximum and second largest measured annual peak discharges were 266 ft^3/s on January 2, 1997 and 252 ft^3/s on December 31, 2005, respectively, both of which were the result of rain-on-snow events associated with unseasonably warm winter storms.

Streamflow recurrence intervals are useful when evaluating the probability of a particular flow event occurring during any given year (Robinson and others, 1998). Changes in recurrence intervals can occur for a stream when significant changes arise in the stream’s discharge pattern. These changes can be caused by natural events or human-related activities. Generally, changes occur more often when recurrence intervals are short rather than when they are long (Robinson and others, 1998). During high discharge events and floods, sediment transport is increased by the increased velocity of flood waters in the channel and increased erosion processes in the drainage basin (Seiler and Wood, 2009, p. 34). Characterizing high discharge events, magnitudes, and frequency helps to understand sediment movement dynamics within the creek.

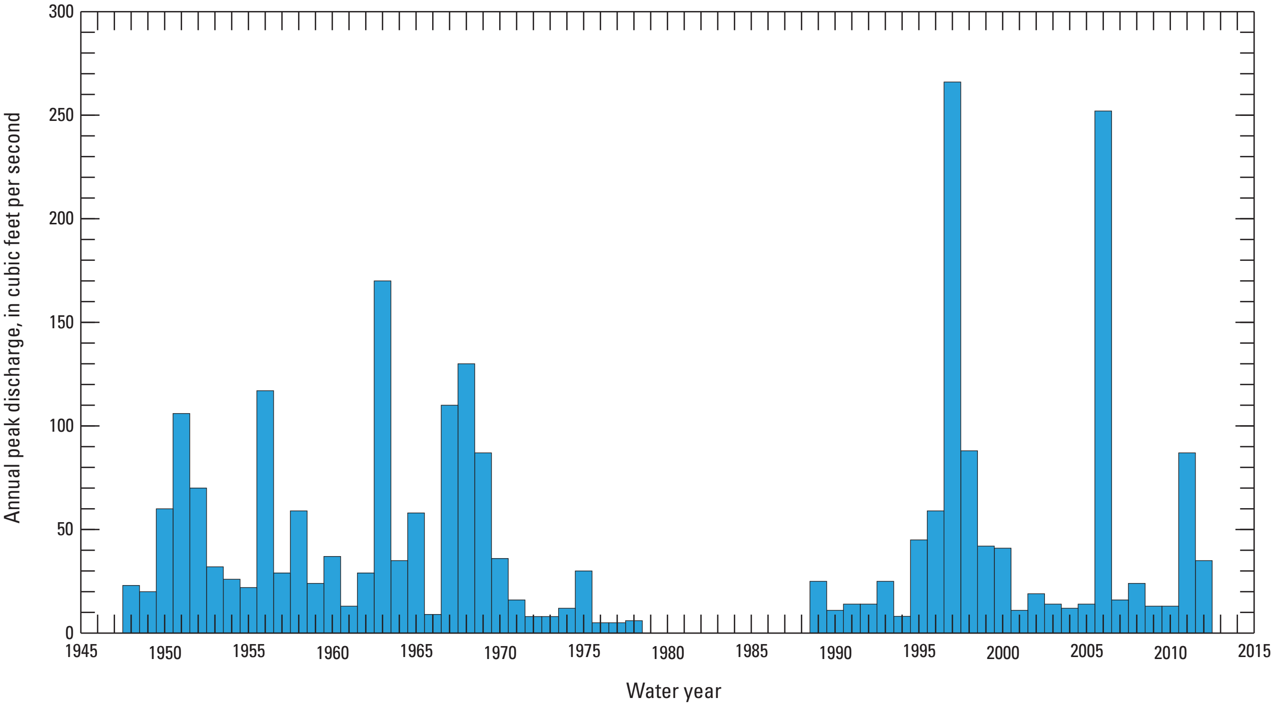

Figure 7. Annual peak discharge at site 2, Clear Creek near Carson City, western Nevada (USGS streamgage 10310500), water years 1948–78 and 1989–2012.

The probability of a peak discharge being exceeded during a water year can be determined with a flood frequency analysis, which is a form of recurrence interval evaluation (Interagency Advisory Committee on Water Data, 1982). A flood frequency analysis using annual peak discharges from 1948 to 1978 found drainage area, mean basin elevation, and latitude were significant in estimating a flood-frequency relationship (Thomas and others, 1997). A new flood-frequency analysis was created using the 55 annual peak discharges (systematic annual peaks) measured at site 2 during 1948–78 and 1989–2012 (fig. 8). This statistical analysis involved computing flood frequency (recurrence) estimates by using an expected moments algorithm (EMA) (Cohn and others, 1997, 2001; Veilleux and others, 2013) and fitting a known statistical distribution model (log-Pearson Type III) to the series of Clear Creek annual peak discharges (Interagency Advisory Committee on Water Data, 1982). The EMA method has been used to characterize recurrence estimates for other streams in the Sierra Nevada in California (Parrett and others, 2011; Gotvald and others, 2012).

Low outliers are peak discharges that are significantly less than other recorded discharges, such as zero flow for a perennial stream during a drought year. The multiple Grubbs-Beck test was used to look for low outliers (Cohn and others, 2013). No annual peak discharges qualified as a low outlier for Clear Creek during 1948–78 or 1989–2012; thus, all annual peak discharges were used in the EMA analysis (U.S. Geological Survey, 2010, 2011, 2012). A generalized skew value of 0.156 was used from Interagency Advisory Committee on Water Data (1982, pl. 1) to adjust the station skew of 0.380 for a weighted skew of 0.309.

The annual exceedance probabilities for the 55 annual peak discharges (U.S. Geological Survey, 2013) using the EMA are plotted in figure 8, and selected annual peak discharge exceedance probabilities and recurrence intervals are shown in table 2. The annual exceedance probability of 1 percent suggests that once every 100 years a flood event in the Clear Creek drainage basin can cause an estimated annual peak discharge of 336 ft^3/s. The maximum observed annual peak discharge of 266 ft^3/s, on January 2, 1997, was estimated to have an annual exceedance probability of 1.8 percent. The second greatest observed annual peak discharge of 252 ft^3/s, on December 31, 2005, was estimated to have an annual exceedance probability of 3.6 percent. The annual peak discharges for 2010 (13 ft^3/s), 2011 (87 ft^3/s), and 2012 (35 ft^3/s) exceeded the 10 percent annual exceedance probability.

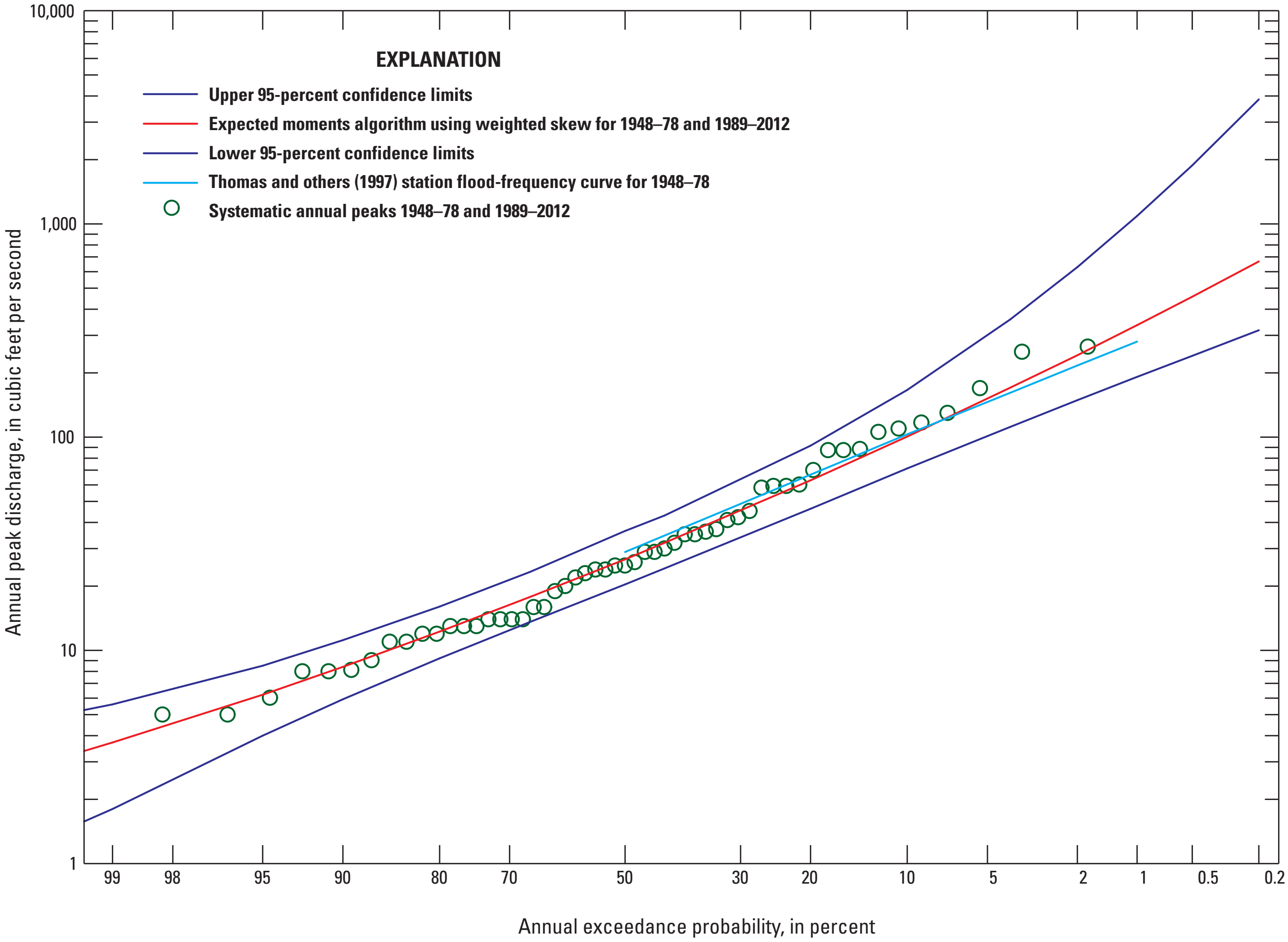

Figure 8. Annual exceedance probability of annual peak discharges for site 2, Clear Creek near Carson City, western Nevada (USGS streamgage 10310500).

Table 2. Annual exceedance probabilities of annual peak discharges for site 2, Clear Creek near Carson City, western Nevada (USGS streamgage 10310500) for water years 1948–78 and 1989–2012 compared to Thomas and others (1997) results.

[–, no data available]

Annual exceedance probability (percent)	Recurrence interval (years)	Annual peak discharge			
		1948–78 and 1989–2012		Thomas and others (1997), 1948–78	
		Gage values	Weighted regional adjustment	Gage values	Weighted regional adjustment
		(cubic feet per second)			
50	2	26	27	29	30
20	5	62	63	67	66
10	10	101	101	103	120
4	25	174	170	162	207
2	50	251	243	217	297
1	100	353	336	282	408
0.5	200	486	456	–	–
0.2	500	725	666	–	–

Sediment and Water-Quality Study Methods

Samples were collected during 2010–12 at three sites on Clear Creek to characterize the sediment-transport characteristics and water quality in three distinct reaches of the creek (fig. 2). These three sites were the same sites where Seiler and Wood (2009) collected and analyzed sediment and water-quality data during 2004–07. Continued data collection at these three sites allows for the comparison of current data to baseline conditions and the evaluation of data over time.

Samples collected at site 1 were collected upstream of the culvert where U.S. Highway 50 crosses Clear Creek at an altitude of 6,620 ft (fig. 2). Site 2 samples were collected just upstream of the concrete weir at the streamgage at an altitude of 5,000 ft. Site 3 samples were collected just downstream of a cement culvert in a dense stand of willows within Fuji Park, which is adjacent to a major commercial development in Carson City at an altitude of 4,765 ft (figs. 1 and 2).

Collection Methods

Samples collected at the three Clear Creek sites were analyzed for sediment (suspended-sediment concentration and bedload), particle-size distribution and sand break, and selected water-quality constituents. Sand break is the fraction of the suspended sediment whose particle size is less than 0.0625 mm. When creek discharge was sufficient, the suspended-sediment samples were collected with a hand-held DH-48 sampler (Edwards and Glysson, 1999) at several points distributed in equal-width increments across the creek. When the depth of water in the stream was less than about 0.5 ft, samples were collected by dipping a glass bottle in the stream at a single point in the centroid of flow.

Samples analyzed for bedload and particle-size distribution were collected using a Helley-Smith bedload sampler (Helley and Smith, 1971) or a BLH-84 sampler (Davis and Federal Interagency Sedimentation Project, 2005; Federal Interagency Sedimentation Project, 2013). The bedload sampler was lowered to the streambed and held in place for 30–60 seconds at each sampling point across the active stream channel. The length of time the sampler was held in place was the same at each point during each sampling event. The bedload sediment transport rate, in tons per day, was computed using the weight of the sample collected, diameter of sampler nozzle, number of sample points, width of each section, width of stream, and the number of seconds the sampler was deployed (Edwards and Glysson, 1999, eq. 4, p. 80).

Field measurements of water temperature, specific conductance, and pH were made prior to collecting samples for chemical analysis at the three sites. Field measurements of water quality were made using the procedures outlined in the USGS National Field Manual (Wilde, variously dated) for the collection of water-quality data. Samples analyzed for chemical analysis were collected with a hand-held DH-81 sampler (Wilde and others, 2014) and sent to the USGS National Water Quality Laboratory (NWQL) in Denver, Colorado, for analysis of major ions, nutrients, trace elements, and pesticides.

Replicate samples of suspended-sediment concentration were collected for quality assurance and quality control (Horowitz and others, 1994) at each of the three Clear Creek sample sites during 2010–12. Each replicate sample was collected within 15 minutes after the regular environmental sample and was assumed to represent similar flow and sediment conditions; however, creek characteristics can be dynamic, which commonly results in some differences between environmental and replicate samples. Relative differences between environmental and replicate suspended-sediment sample concentrations at site 1 (n=11) ranged from 0 to 66 percent (median coefficient of variation of 26 percent). One replicate sample, however, was 142 percent lower than the environmental sample and may have been caused by small differences in the way the sediment samples were collected between replicates. Site 2 replicate samples (n=18) were generally in good agreement, with differences ranging from 0 to 50 percent; however, one replicate sample was 133 percent lower than the environmental sample, which is attributed to differences in sample collection methods between replicates (median coefficient of variation of 10 percent). Site 3 replicate samples (n=11) were in mostly good agreement with differences ranging from 0 to 22 percent (median coefficient of variation of 3 percent). Given the degree of variability in suspended-sediment concentrations between the environmental and replicate samples from the headwaters to the downstream reach of the study area, definitive changes in suspended-sediment transport characteristics will likely be more apparent at downstream reaches in the stream than in the headwaters.

Several statistical tests, the Mann-Whitney Rank-Sum and the t-test, were used throughout the sediment and water-quality data analysis in this study to determine whether two datasets were statistically different. Instances where differences between datasets were not significant indicate that the samples collected during 2010–12 are still representative of what is considered baseline conditions. Alternatively, instances where differences between datasets were significant indicate that sediment transport in Clear Creek is different from baseline conditions. The Mann-Whitney Rank-Sum test was used most often because it can compare two groups of data without the required assumptions of normality (Helsel and Hirsch, 2002, p. 118). The t-test also was used in the few instances where the two datasets were normally distributed (Helsel and Hirsch, 2002, p. 124). The t-test is more powerful in distinguishing significant differences among data that are normally distributed; however, it requires normality. The Mann-Whitney Rank-Sum, although not as powerful as the t-test, is more widely applicable to environmental data because often times environmental data are not normally distributed. A significance test also was used to assess whether correlations among various parameters were significantly different from one another as represented during both periods of evaluation (Cohen and others, 2003, p. 272–274). With all these statistical significance tests, a p-value less than 0.05 is considered indicative of a significant difference between the two datasets.

Sediment Concentration and Transport

As part of this study, samples for analyses of suspended- and bedload-sediment and water quality were collected during periods of base flow, storm events, and throughout the snowmelt-runoff period at the three sample sites (fig. 9, appendixes 1–3). Collection of samples over a wide range of stream discharges and over several years is important to more accurately depict sediment transport characteristics during all flow regimes (Uhrich and Bragg, 2003). With the exception of water year 2010, sampling during this study was generally initiated when peak discharges occurred (fig. 9). During runoff and base-flow conditions, all three sites were sampled on the same day, if possible. During some spring runoff events, only the lower portions of the drainage were contributing runoff; therefore, the high altitude site 1 was not sampled. More suspended-sediment and bedload samples were collected at the site 2 streamgage than at sites 1 or 3. Water-quality samples were collected at all three sites on the same day, except on September 30, 2010, when a sample was collected only at site 2.

Suspended-Sediment Concentrations

Suspended-sediment concentrations analyzed from samples collected during 2010–12 ranged from less than 0.5 to 33 mg/L at site 1, from 4 to 526 mg/L at site 2, and from 1 to 123 mg/L at site 3 (appendix 1; fig. 10*A*). Qualitatively, suspended-sediment concentrations over the period of record (2004–07 and 2010–12) were highest at site 2 (figs. 10*A*–10*B*). Generally, discharge during 2010 was consistently less than mean daily discharge for the period of record water years (fig. 5*A*), which appeared to influence the suspended-sediment concentration, most noticeably at site 2 but also, to a lesser extent, at site 3. The median suspended-sediment concentration determined for samples collected from site 2 during 2010 (9 mg/L) was nearly six times lower than those from 2011 and 2012 (68 and 52 mg/L, respectively), which resulted in the greater variability shown in the suspended-sediment data during 2010–12 than during 2004–07 (fig. 10*B*).

Suspended-sediment concentrations at each of the three Clear Creek sampling sites were within the same range as samples collected during 2004–07, suggesting that concentrations are within what can be considered base line (fig. 10). Generally, suspended-sediment concentrations were higher in the lower reaches of Clear Creek (sites 2 and 3) than in the upper drainage basin (site 1). Suspended-sediment concentrations were not statistically different between sites 2 and 3 during 2004–07 (fig. 10*B*) or between sites 1 and 3 during 2010–12 (fig. 10*A*). Overall, variability in suspended-sediment concentration was highest at site 3, largely because of the maximum concentration of 1,150 mg/L measured on May 2, 2006, when discharge reached 23 ft^3/s (greater than the 80th percentile in flow for Clear Creek).

An analysis was performed to better understand how suspended-sediment concentrations vary under changing discharge. For each Clear Creek sampling site, paired discharge and suspended-sediment concentration values were used to plot figure 11, which includes data for 2004–07 and 2010–12. The range in stream discharge is plotted in a flow duration format (similar to fig. 6) showing the percentile discharge values for Clear Creek. The specific cubic feet per second discharge that constitutes high, moderate, and low discharges is site specific. Each boxplot shows the range in suspended-sediment concentrations measured in association with specific ranges of discharge. For example, at site 1 (fig. 11*A*), suspended-sediment concentrations ranged from about 1 to 16 mg/L when stream discharge ranged from about 2 to 5 ft^3/s (shown within the 75th to 90th percentile [high] discharge zone). Generally, the relations between suspended-sediment concentrations and discharge were similar between the 2004–07 and 2010–12 datasets and, therefore, the data were combined in the evaluations shown in figures 11*A*–11*C*.

For the period of record (2004–07 and 2010–12), suspended-sediment concentrations at site 1 ranged from 1 to 155 mg/L over a 0.12–8.7 ft^3/s range in discharge (fig. 11*A*). Suspended-sediment concentrations measured at site 1 during high, moderate, or low discharges were not statistically different ($p>0.05$). The drainage basin's granitic composition upstream of site 1 may explain why suspended-sediment concentration differences were not measured under varying discharge. Although differences were not statistically significant, suspended-sediment concentrations were slightly elevated at discharges greater than 5.2 ft^3/s (fig. 11*A*). Discharge and suspended-sediment concentrations for site 1 between 2004–07 and 2010–12 datasets were similar (not statistically different, $p=0.619$ and 0.098, respectively, not shown in fig. 11*A*); however, the median suspended-sediment concentration for 2010–12 (4 mg/L) was more than two times lower than median concentration for 2004–07 (8.5 mg/L) (fig. 10).

For the period of record (2004–07 and 2010–12), suspended-sediment concentrations at site 2 ranged from 3 to 526 mg/L over a 0.79–110 ft^3/s range in discharge (fig. 11*B*). Suspended-sediment concentrations measured at site 2 during moderate and low discharges were not statistically different; however, higher suspended-sediment concentrations measured during discharges greater than 16 ft^3/s were statistically significant (high discharge; fig. 11*B*). Discharge and suspended-sediment concentrations between 2004–07 and 2010–12 datasets were similar ($p=0.950$ and 0.302, respectively, not shown in fig. 11*B*); however, the median suspended-sediment concentration for 2010–12 (42.5 mg/L) was more than two times higher than the median concentration for 2004–07 (21 mg/L) (fig. 10).

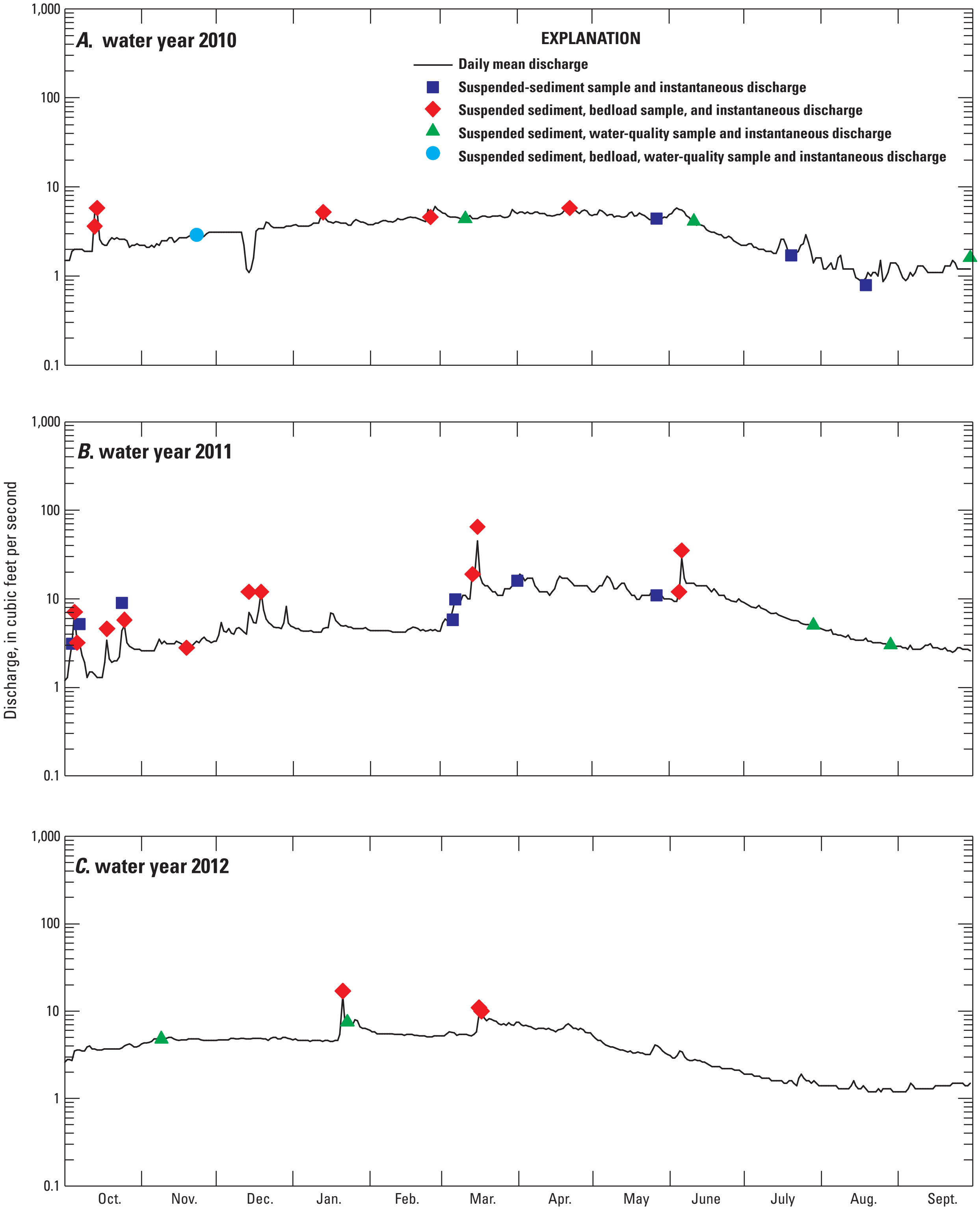

Figure 9. Dates and types of samples collected and daily mean discharge for water years (*A*) 2010, (*B*) 2011, and (*C*) 2012, at site 2, Clear Creek near Carson City, western Nevada (USGS streamgage 10310500).

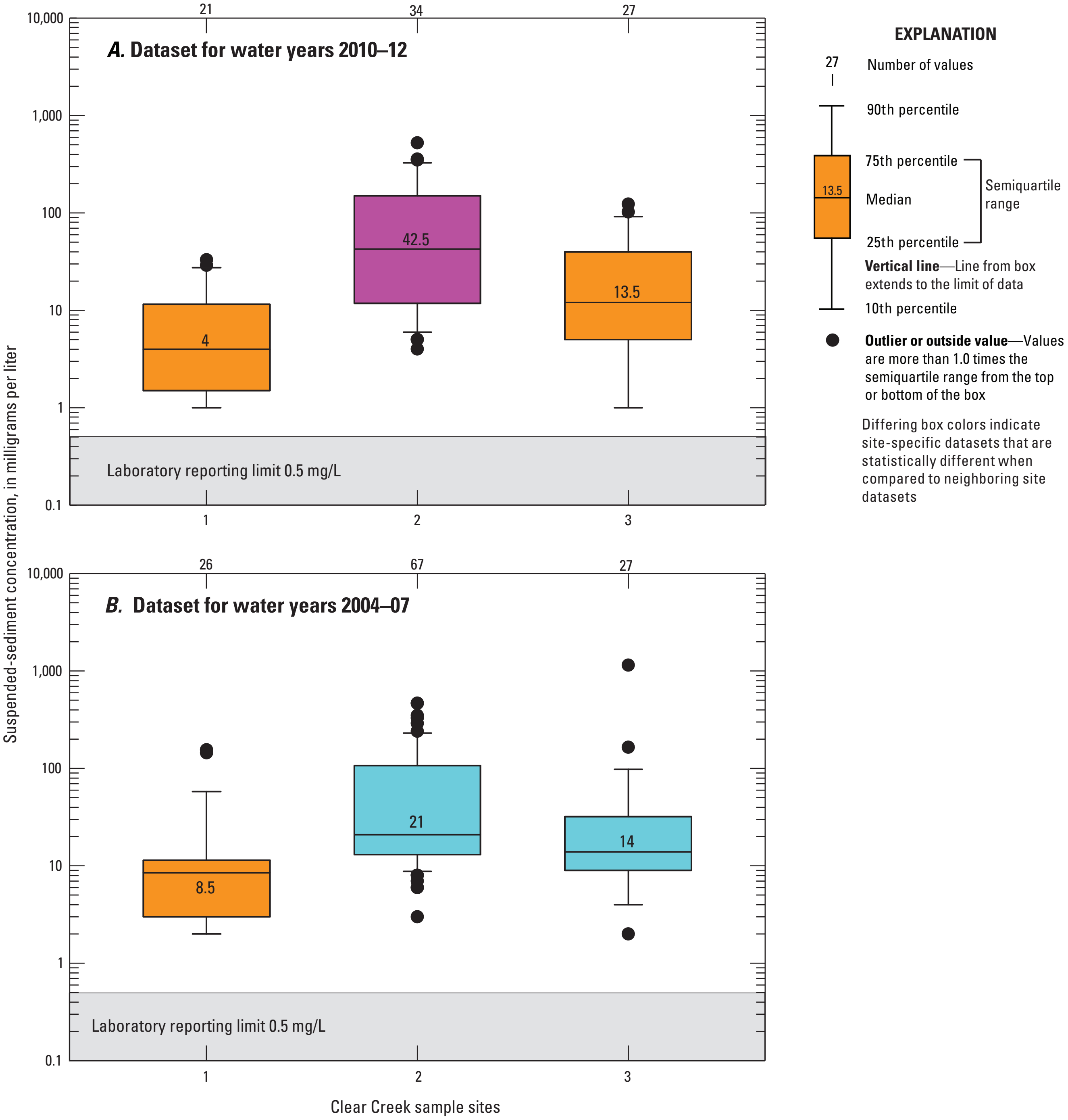

Figure 10. Distribution of suspended-sediment concentration at sites 1, 2, and 3 on Clear Creek, western Nevada, during water years (*A*) 2010–12 and (*B*) 2004–07.

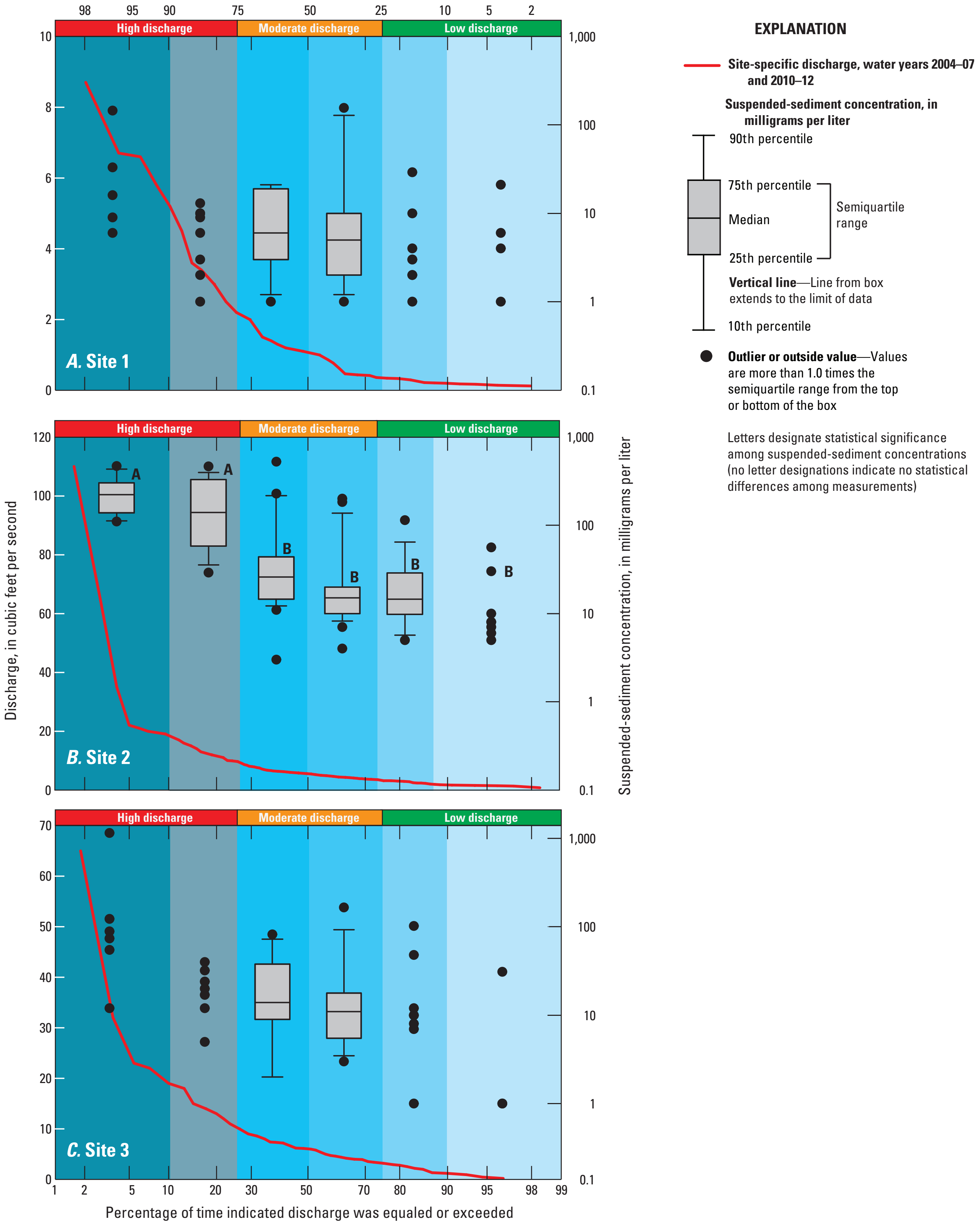

Figure 11. Ranges of suspended-sediment concentrations measured under specified ranges of discharge at (*A*) site 1, (*B*) site 2, and (*C*) site 3, Clear Creek, western Nevada, water years 2004–07 and 2010–12. The flow duration curve is plotted using discharge measurements during paired discharge measurement and suspended-sediment sample collection.

For the period of record (2004–07 and 2010–12), suspended-sediment concentrations at site 3 ranged from 1 to 1,150 mg/L over a 0.16 to 65 ft^3/s range in discharge (fig. 11*C*). Suspended-sediment concentrations measured at site 3 during high, moderate, or low discharges were not statistically different ($p>0.05$). Although differences were not statistically significant, suspended-sediment concentrations were elevated when discharges were greater than 19 ft^3/s (fig. 11*C*). Sediment deposition has been documented to occur upstream of site 3 (PBS&J, 2003; Seiler and Wood, 2009), which may explain why median suspended-sediment concentrations under varying discharge were not statistically different. Discharge and suspended sediment concentrations between 2004–07 and 2010–12 datasets were similar ($p=0.258$ and 0.445, respectively, not shown in fig. 11*C*).

Some suspended-sediment samples also were analyzed for the percentage by weight of samples finer than 0.0625 mm, also known as the sand break. This represents the sediment diameter threshold between sand and silt. At all sites, most suspended sediment was silt sized or finer (table 3). Median suspended-sediment concentrations (table 3) were calculated only from samples that were collected at the same time that samples were analyzed for sand break. Although data are limited, the percentage of silt content generally increased from upstream to downstream. Comparison of the percentage between the 2004–07 and the 2010–12 datasets also indicates a possible increase in median silt-size percentage by weight (table 3).

The relation between suspended-sediment concentration and the silt percentage by weight is not consistent between sites or water year datasets (fig. 12). Site 1 shows a correlation ($R^2=0.95$) for the 2004–07 dataset between the increase in suspended-sediment concentrations and the decrease in percentage of the sample (by weight) comprised of fines (fig. 12*A*). However, this relationship is not observed in the 2010–12 dataset. No relation between concentration and percent fines is apparent at site 2; however, the limited data suggests that the sand break has increased over time (fig. 12*B*; table 3). When the sand break increases, more suspended sediment is finer than 0.0625 mm (by weight). Generally, at site 3, no relation between concentration and percent fines is apparent (fig. 12*C*); however, during 2010–12, concentration and sand break held nearly constant.

Sediment Loads

Suspended-Sediment Loads

Suspended-sediment loads, in tons per day (ton/d), were calculated by multiplying paired stream discharge and suspended-sediment concentration. During this study (2010–12), suspended-sediment loads ranged from 0 to 0.52 ton/d at site 1, 0.01 to 40 ton/d at site 2, and 0 to 13 ton/d at site 3 (fig. 13*A*, appendix 1). Suspended-sediment loads were almost always lower at sites 1 and 3 than at site 2 (fig. 13*A*–13*B*), indicating that sediment was being mobilized in reach 2 (between sites 1 and 2). Suspended-sediment loads were highest at site 2 (fig. 13). The single highest suspended-sediment load was observed at site 2 during a precipitation event that occurred in late December 2005 (fig. 13*B*). This event produced a suspended-sediment load of 86 ton/d in Clear Creek when discharge reached 110 ft^3/s.

Table 3. Median percentage of suspended sediment finer than 0.0625 millimeters by weight for Clear Creek, western Nevada, water years 2004–07 and 2010–12.

[Sample counts and median values represent only suspended-sediment samples where sand break analysis was done. USGS site identification shown in parentheses after site name. **Abbreviations:** mg/L, milligram per liter; mm, millimeter]

Water year dataset	Site 1			Site 2			Site 3		
	Clear Creek above Highway 50, near Spooner Summit (10310485)			Clear Creek near Carson City (10310500)			Clear Creek at Fuji Park, at Carson City (10310518)		
	Number of samples	Median suspended-sediment concentration (mg/L)	Median suspended-sediment percent finer than 0.0625 mm by weight	Number of samples	Median suspended-sediment concentration (mg/L)	Median suspended-sediment percent finer than 0.0625 mm by weight	Number of samples	Median suspended-sediment concentration (mg/L)	Median suspended-sediment percent finer than 0.0625 mm by weight
2004–07	14	9.5	58	26	14.5	48.5	14	13	76.5
2010–12	11	6	64	19	42	77	14	18	86.5

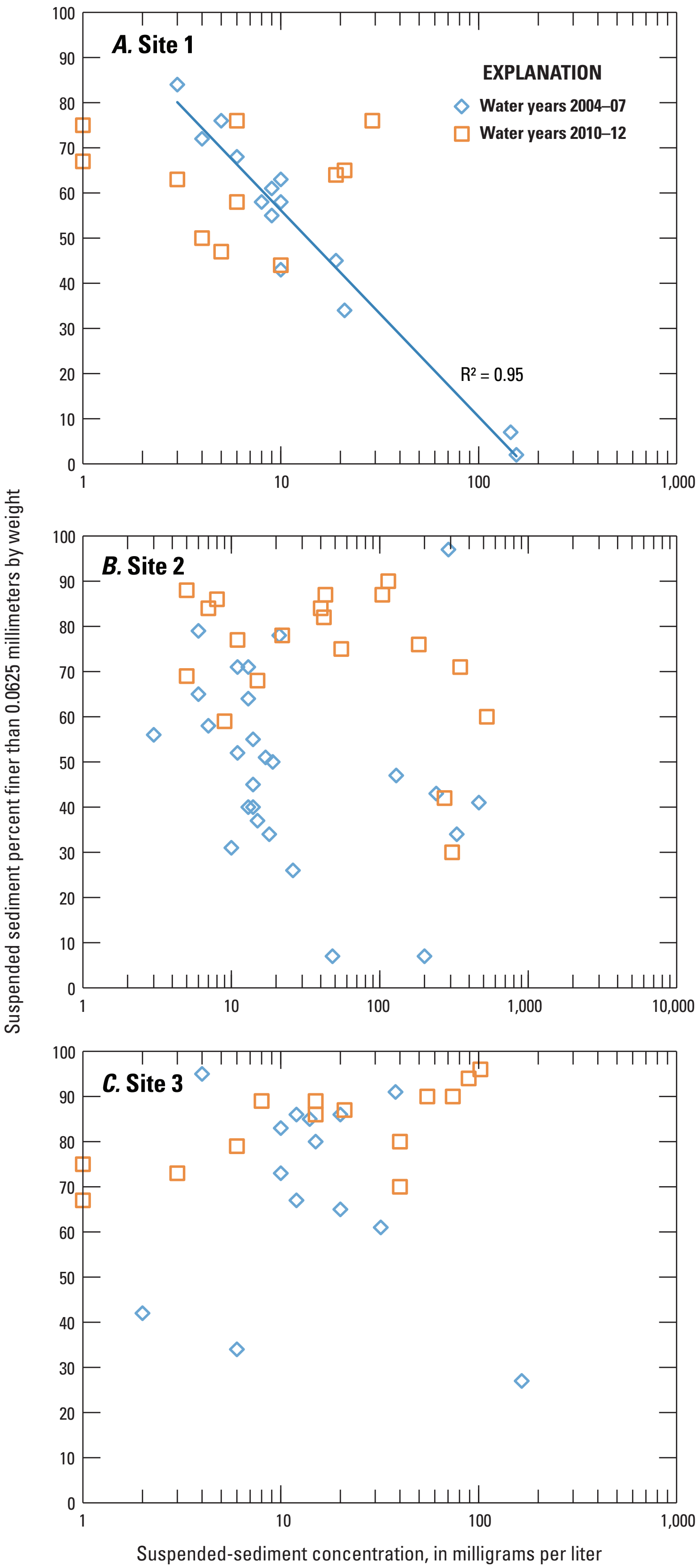

Figure 12. Relation between suspended-sediment concentration and sand break for (*A*) site 1, (*B*) site 2, and (*C*) site 3, Clear Creek, western Nevada, water years 2004–07 and 2010–12.

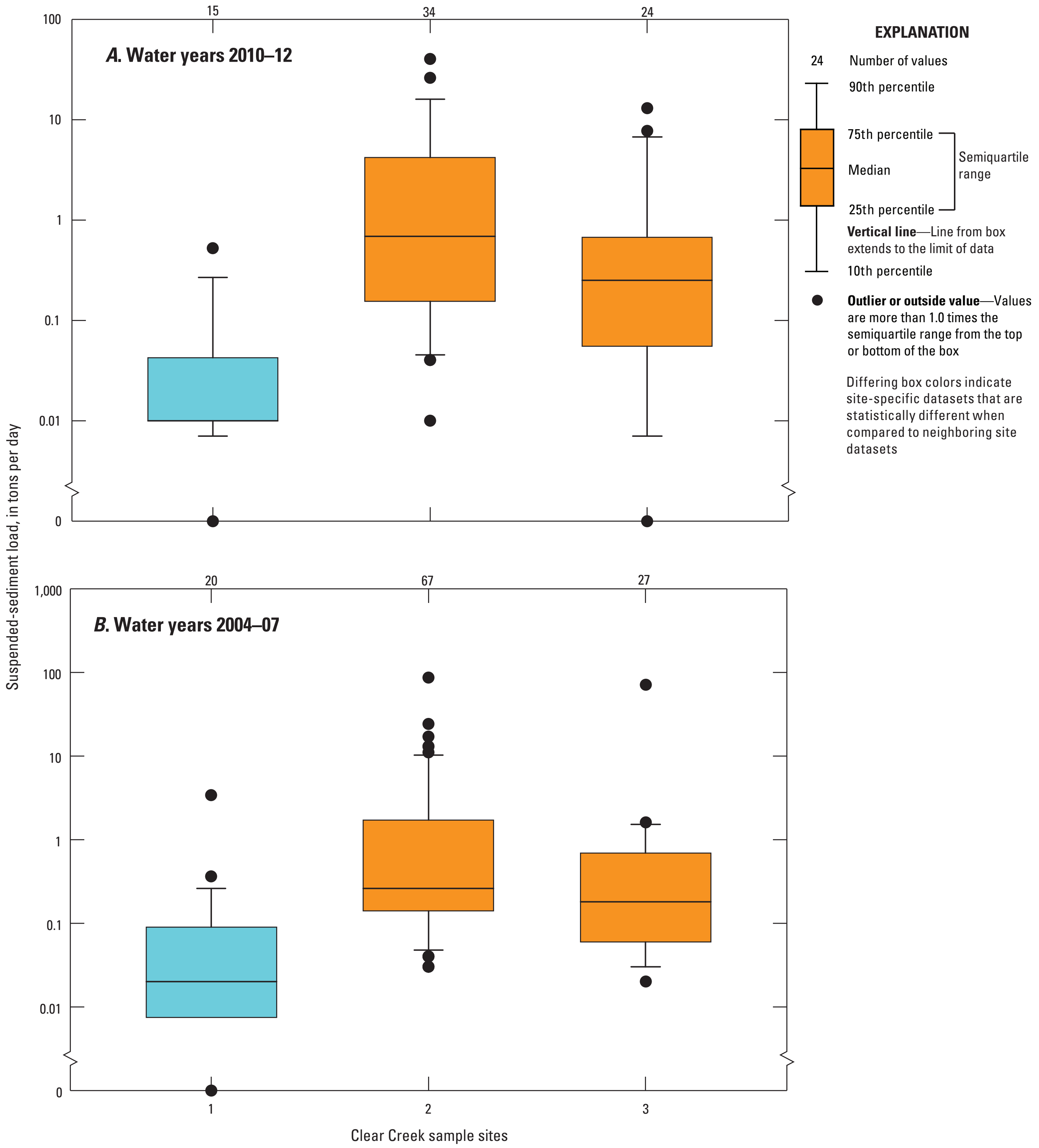

Figure 13. Distribution of suspended-sediment loads at sites 1, 2, and 3 on Clear Creek, western Nevada, water years (*A*) 2010–12 and (*B*) 2004–07.

Analyzing suspended-sediment loads with associated instantaneous discharge helps characterize Clear Creek sediment-transport dynamics. Seiler and Wood (2009) presented a relation between sediment loads to discharge (for 2004–07) using simple linear regression conducted on a logarithm transformation. This required the application of a bias-correction factor to bring the transformed sediment load data back into the non-logarithmic units of tons (Helsel and Hirsch, 2002, chap. 9). The bias correction factors applied by Seiler and Wood (2009) were updated and the updated corrections used to re-compute the annual suspended-sediment loads during 2004–07 (table 4). The recalculated annual suspended-sediment loads were 6–7 percent higher than originally determined (table 1 from Seiler and Wood, 2009; table 4).

The same logarithm transformation analysis between suspended-sediment loads and discharge were done at each Clear Creek site using the 2010–12 dataset. The comparison between 2004–07 and 2010–12 highlights the range in suspended-sediment loads (fig. 14). The slope of the trend lines at site 1 (fig. 14*A*, equation shown in explanation) suggests a small decrease in suspended-sediment load for the same discharge between datasets. The slope of the trend line at site 3 (fig. 14*C*) suggests a decrease in suspended-sediment transport rates at lower discharges and higher rates at discharge greater than 30 ft^3/s. However, the difference in slope between 2004–07 and 2010–12 datasets is not significant for either site 1 or 3 ($p=0.85$ and $p=0.61$, at sites 1 and 3, respectively; Cohen and others, 2003). The similar trend-line slopes at site 2 between 2004–07 and 2010–12 datasets indicate no significant change in suspended-sediment load for the same discharge ($p=0.76$, fig. 14*B*).

Suspended-sediment loads were plotted with associated Clear Creek discharge in a flow duration format to better understand how suspended-sediment loads at each site vary under different discharge conditions (figs. 15*A*–15*C*). For the period of record (2004–07 and 2010–12), suspended-sediment loads at all sites associated with high discharge were statistically greater than loads associated with low discharge (figs. 15*A*–15*C*). Site 1 shows significantly higher suspended-sediment loads associated with high discharge greater than about 2.2 ft^3/s ($p<0.05$; fig. 15*A*). Suspended-sediment loads at sites 2 and 3 generally were similar during high and moderate discharges; however, significantly lower during low discharge ($p<0.05$; figs. 15*B*–15*C*). Suspended-sediment loads generally were significantly higher at discharge greater than 5.5 and 3.2 ft^3/s at sites 2 and 3, respectively.

Suspended-sediment loads are almost always lower at sites 1 and 3 than at site 2 during both high and low discharges ($p<0.05$, figs. 15*A*–15*C*). New data (2010-12) continues to support the findings of Seiler and Wood (2009) in that sediment deposition occurs between sites 2 and 3 during high discharge (generally when site 2 discharge exceeds 9 ft^3/s).

Table 4. Coefficients and bias-correction factors for logarithm transformation analysis of suspended-sediment and bedload-transport rates for sampling sites in Clear Creek, western Nevada.

[**Abbreviations:** Q, stream discharge; R, revised; SS, suspended sediment; R^2, coefficient of determination]

Site No. (see fig. 1)	Water years	Dependent variable	Number of samples	Slope	Intercept	Bias-correction factor	Trend line coefficient of determination (R^2)	Trend line equation
1	2004–07	SS load	26	1.34	-1.67	2.13R	0.7	log(SSload)=1.34*log(Q)-1.67
1	2010–12	SS load	21	1.1	-1.93	1.87	0.54	log(SSload)=1.10*log(Q)-1.93
2	2004–07	SS load	68	2.13	-1.92	1.09R	0.77	log(SSload)=2.13*log(Q)-1.92
2	2010–12	SS load	60	1.95	-1.49	1.58	0.65	log(SSload)=1.95*log(Q)-1.49
2	2004–07	Bedload	11	1.36	-0.52	1.34R	0.62	log(Bedload)=1.36*log(Q)-0.43
2	2010–12	Bedload	20	1.56	-0.94	0.01	0.68	log(Bedload)=1.56*log(Q)-1.49
3	2004–07	SS load	26	1.40	-1.58	2.82R	0.51	log(SSload)=1.40*log(Q)-1.56
3	2010–12	SS load	26	1.77	-2.08	1.9	0.8	log(SSload)=1.77*log(Q)-2.08

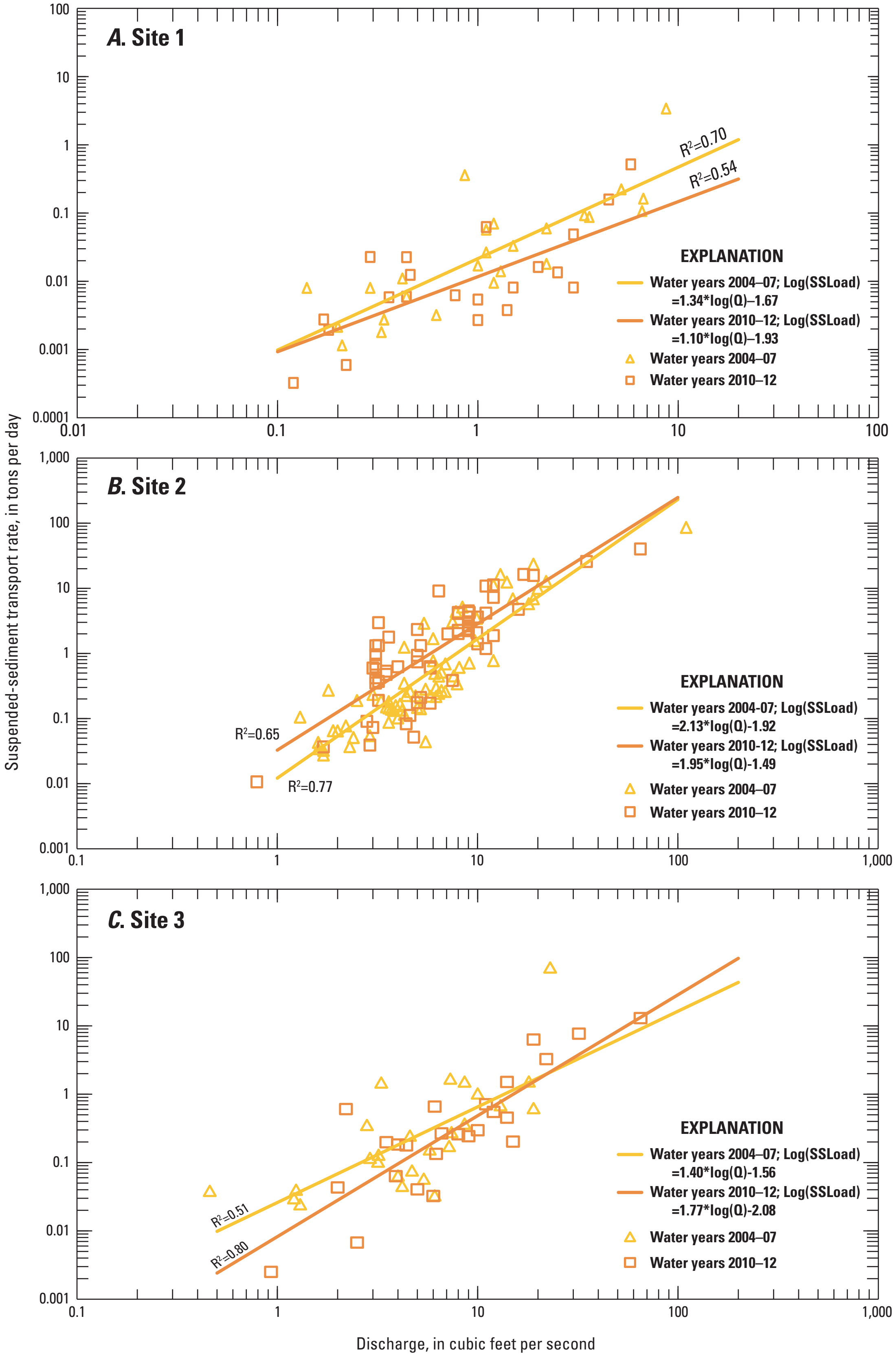

Figure 14. Relation between suspended-sediment transport rate and instantaneous discharge for (*A*) site 1, (*B*) site 2, and (*C*) site 3, Clear Creek, western Nevada. Equations and associated simple linear regression analysis information are provided in table 4.

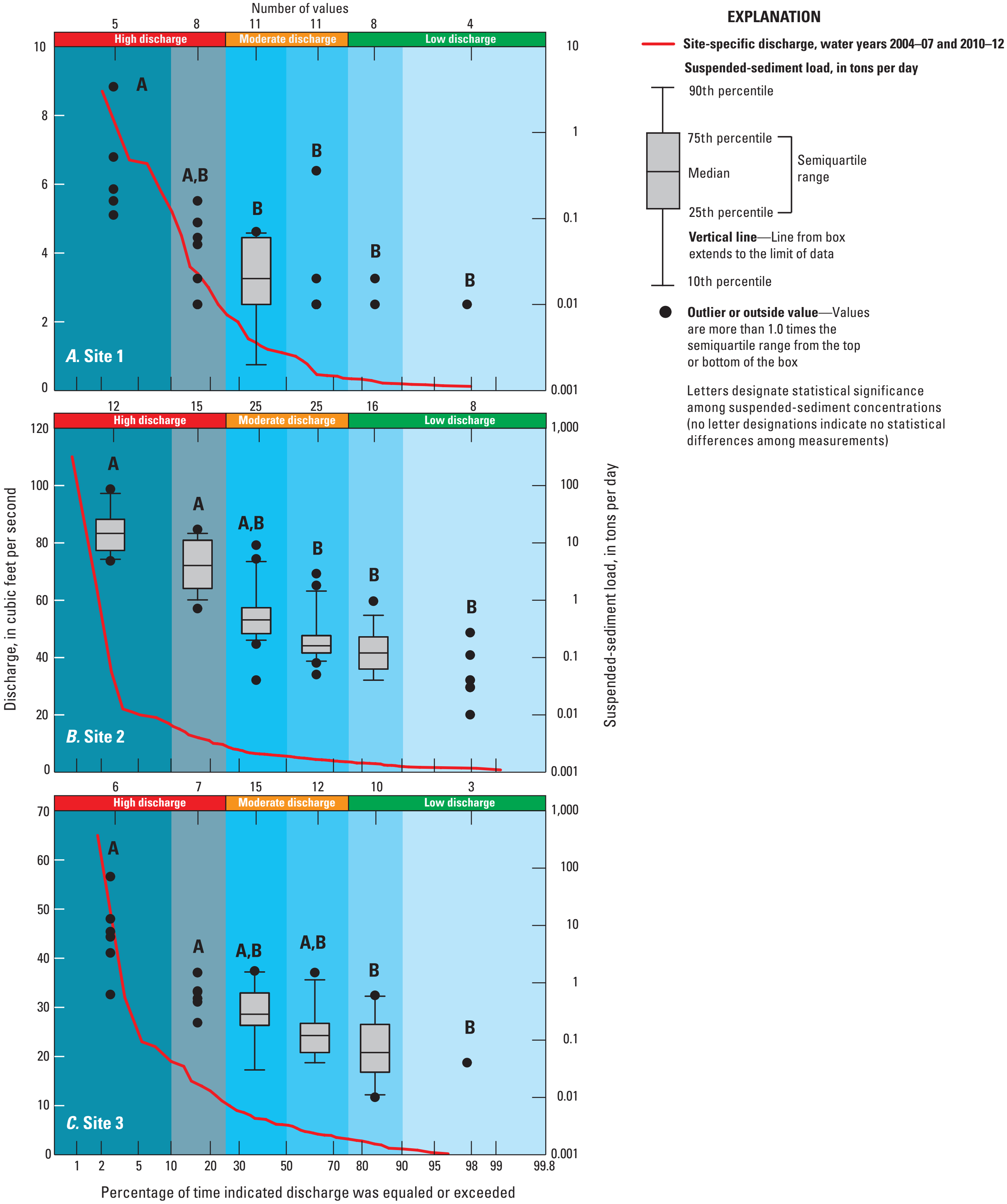

Figure 15. Suspended-sediment loads measured under specified ranges of discharge at (*A*) site 1, (*B*) site 2, and (*C*) site 3, Clear Creek, western Nevada, water years 2004–07 and 2010–12. The flow duration curve is plotted using only those discharge measurements associated with a suspended-sediment sample.

Bedload

Bedload, the material rolling or bouncing along the bed of the stream, was sampled during varying discharge conditions during 2010–12 at the three Clear Creek sites (appendix 2, fig. 16). Generally, bedload only occurs when a threshold discharge in the creek is reached that provides sufficient force to dislodge material from the creekbed. The threshold discharge can vary from site to site because of creekbed characteristics such as grade and bed material size/weight. During one visit to site 1 on June 6, 2011, bedload material was observed moving in the channel. The creek discharge at that time (5.8 ft^3/s) was high enough to warrant bedload sampling (appendix 2; fig. 16). This was the only bedload-sediment sample collected from site 1 during the 2010–12 study. During the 2004–07 study, bedload material was sampled when streamflow was about 0.3 ft^3/s. Bedload was observed moving in the channel at discharges greater than or equal to 2.8 ft^3/s at site 2 and 1.5 ft^3/s at site 3 (21 and 11 samples, respectively). Sampled bedload was 0.74 ton/d at site 1 (one sample only), ranged from 0.07 to 14.07 ton/d at site 2 and ranged from 0.03 to 4.65 ton/d at site 3 (appendix 2).

The same logarithm transformation analysis used to evaluate a relation between suspended sediment and discharge was performed between bedload and discharge for all samples collected during 2010–12 at site 2 (fig. 16). The bias correction factors applied by Seiler and Wood (2009) to the 2004–07 dataset were updated and the updated corrections were used to re-compute the annual suspended-sediment loads during 2004–07 (table 4). The recalculated annual suspended-sediment loads were 2–16 percent higher than originally determined (table 1 from Seiler and Wood, 2009; table 4). The coefficient of determination (R^2) indicates that discharge accounts for only about 60–70 percent of the variability in the data (2004–07 dataset = 0.62 and 2010–12 dataset = 0.68; fig. 16). The scatter observed in the data is not unexpected given the variation in precipitation, snowmelt, channel stability, source material (local geology), and other factors during each discharge event. In comparing the two datasets, the bedload data collected from site 2 as part of this study showed a different relation to discharge than that determined by Seiler and Wood (2009). For a given discharge, there was less bedload sediment in 2010–12 than in 2004–07 (fig. 16). Although uncertain, an explanation for lower bedload could include changes in the drainage basin affecting bedload source material.

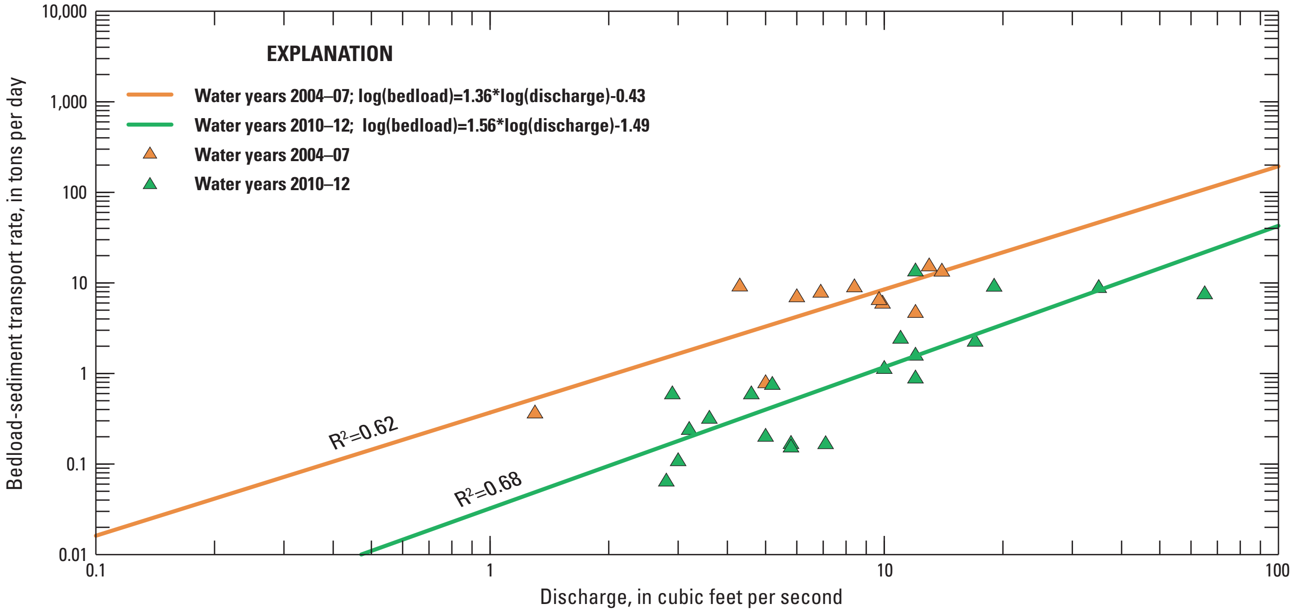

Figure 16. Relation between bedload and discharge at site 2, Clear Creek, western Nevada, water years 2004–07 and 2010–12.

Bedload samples were collected on the same day at sites 2 and 3 on nine different dates during 2010–12 (appendix 2). Bedload was not statistically different between sites on those days (p=0.60) or between the entire site 2 and site 3 bedload datasets from 2010 to 2012 (p=0.63).

Bedload samples from the Clear Creek sites were analyzed for particle size by weight fractions (appendix 2). The particle-size distributions were used to determine the silt, sand, and gravel composition of each bedload sample collected at sites 2 and 3 and then compared to the discharge at the time of sample collection (figs. 17 and 18). Silt is categorized as sediment particles less than 0.0625 mm in diameter; sand-sized sediment is considered particles greater than 0.0625 mm and less than or equal to 2 mm in diameter; whereas gravel-sized sediments are considered particles with a diameter greater than 2 mm. Bedload sample composition from site 2 in 2010–12 was composed of mostly sand-sized sediment with very little silt (generally less than 1 percent; figs. 17*A*–17*C*). Gravel-sized sediment contributed to the bedload composition only when discharge equaled or exceeded 2.8 ft^3/s and generally dominated the composition, by weight, when discharge exceeded 12 ft^3/s. Discharges exceeding 10 ft^3/s exceed the 90th percentile of discharge for Clear Creek at site 2 and, therefore, can be considered very high discharge conditions (fig. 6).

Bedload sample composition from site 3 in 2010–12 was composed of dominantly sand-sized sediment with very little silt (generally less than 0.15 percent of total sample) (appendix 2; figs. 18*A*–18*B*). Gravel was observed in nearly all bedload samples and generally contributed between 2 and 15 percent to the total bedload composition, by weight, when present. Gravel movement was observed at a discharge as low as 1.5 ft^3/s; however, gravel movement varied greatly.

Bedload was sampled twice on April 22, 2010, at sites 2 and 3 (figs. 9*A*, 17, and 18) within 25 minutes of each other. Although there was no recorded change in discharge between the replicate samples; measured bedload increased from the first to the replicate sample. Why this bedload surge occurred is uncertain, or if it in fact did occur (this could be attributed to a sample-collection error).

Total Sediment Loads

Total annual sediment load, the summation of suspended-sediment load and bedload, was computed at site 2 during 2010–12 and compared to loads from 2004 to 2007 (table 5). Annual suspended-sediment and bedloads were computed for site 2 using the daily discharge from the site 2 streamgage and the relation between discharge and suspended-sediment load and bedload shown in figures 14 and 16. Loads for the 2004–07 dataset were recomputed based on the revised bias-correction factors. Total sediment loads are a function of stream discharge and therefore vary greatly by year (fig. 19). Total sediment loads ranged from 355 ton/yr in 2010 to 5,460 ton/yr in 2006 (table 5) and were significantly lower during 2010–12 versus 2004–07 periods (p<0.001). Bedload represented between 72 and 90 percent of the total sediment load in 2004–07 and between 29 and 38 percent of total sediment load in 2010–12, which suggests a decrease in bedload between datasets (p=0.054). Mean daily discharge was significantly lower in 2010–12 (p=0.026) than in 2004–07 and may be the reason for the decrease in bedload that results in decreased total sediment load.

An estimate of total sediment yield was calculated for site 2 to evaluate the total load of sediment transported in Clear Creek per square mile of contributing drainage basin (table 5). The drainage basin contributing area to site 2 is 15.4 mi^2 (fig. 2), which includes the 2.4 mi^2 upstream drainage basin area contributing to site 1. Total sediment yield at site 2 ranged from 68 to 352 $(ton/mi^2)/yr$ during 2004–07 and 23 to 114 $(ton/mi^2)/yr$ during 2010–12 (table 5).

Water-Quality Characteristics

Clear Creek water samples were collected and analyzed for selected major inorganic ions, trace metals, nutrients, and pesticides at least twice per water year during 2010–12 (appendix 3). With the exception of the sample collected on September 30, 2011, from site 2, all water-quality samples were collected at each site on the same day in order to give a snapshot of Clear Creek water quality with distance downstream on that given day. Although no quality-control samples were collected for water quality, all results are assumed accurate and representative of the chemical characteristics of Clear Creek.

Seiler and Wood (2009) found the Clear Creek water to be a dilute calcium/sodium bicarbonate type with low nutrient concentrations. Although the number of total samples collected during this study was limited, they continued to represent this same water type (appendixes 1 and 3). Pesticides were only sampled for at site 2 and there were no detections.

Field measurements of water temperature, pH, and specific conductance were made at the three Clear Creek sites prior to the collection of water-quality and most suspended-sediment samples (appendix 1); therefore, field measurements were monitored more frequently than other water-quality constituents (appendix 3). During this study, measured temperatures in Clear Creek ranged from 1.0 to 17.2 °C (appendix 1). At the three Clear Creek sites, pH ranged from 6.9 to 8.2, which was similar to the observed ranges during 2004–07.

The specific conductance of water is a measure of water's capacity to conduct electrical current and is a method of measuring the ionic content of a sample. For most waters, the primary major inorganic ions which contribute to the specific conductance include calcium, magnesium, sodium, potassium, carbonate, chloride, and sulfate. Specific-conductance measurements in Clear Creek ranged from 46 to 234 µs/cm during 2010–12 (fig. 20).

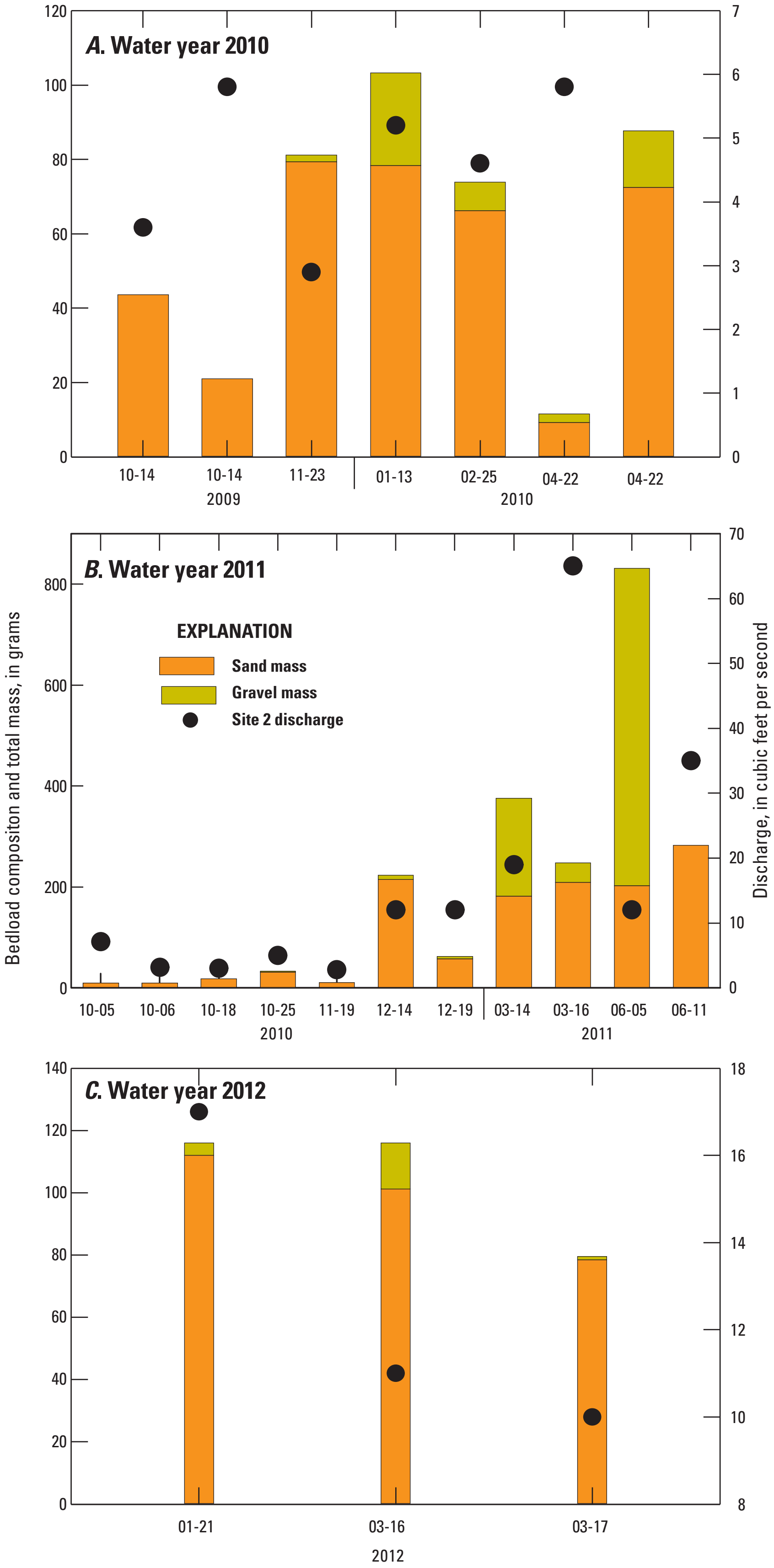

Figure 17. Bedload composition and associated discharge at site 2, Clear Creek near Carson City, western Nevada (USGS streamgage 10310500), water years (*A*) 2010, (*B*) 2011, and (*C*) 2012. When present, the contribution of silt to total bedload mass was generally less than 1 percent.

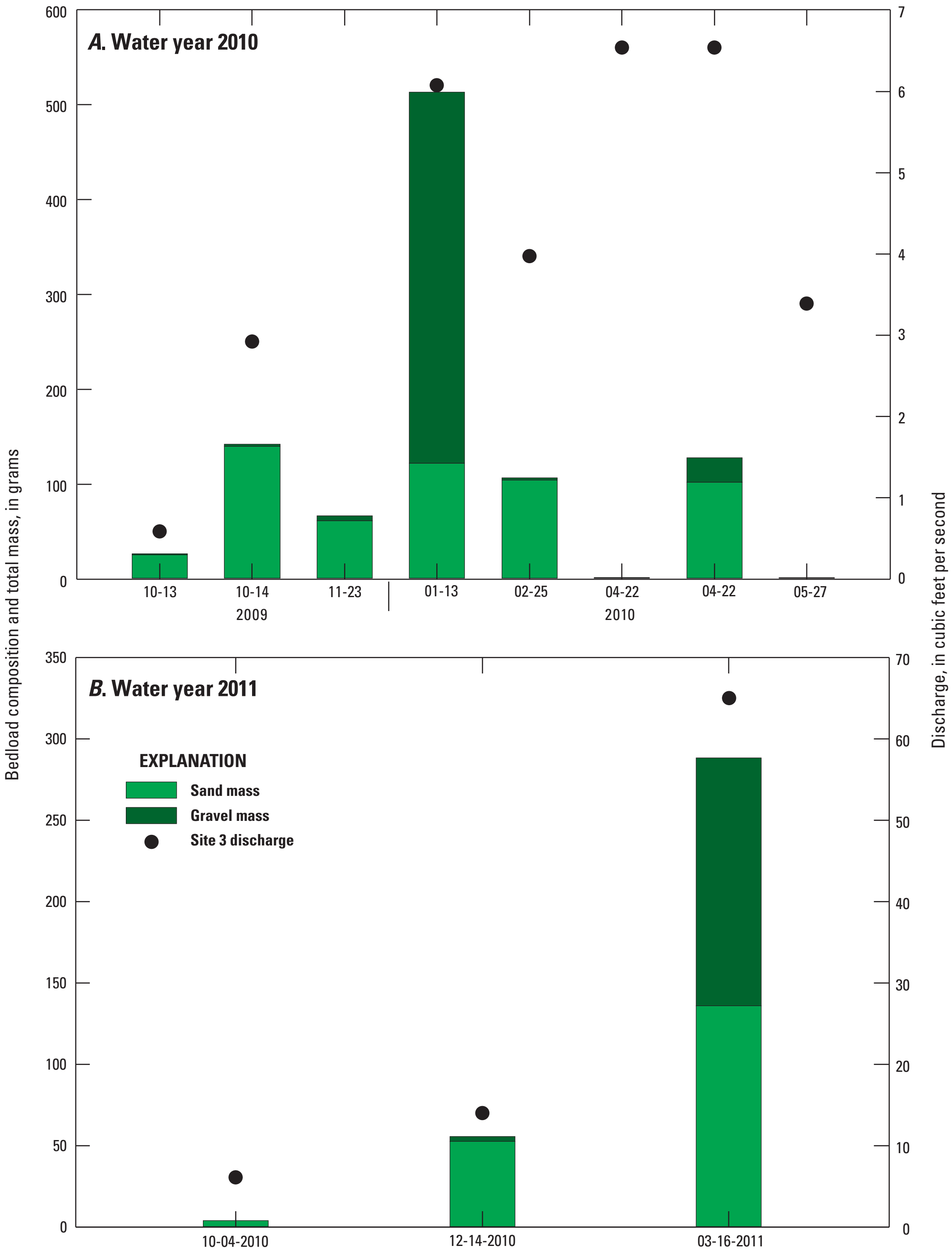

Figure 18. Bedload composition and associated discharge at site 3, Clear Creek, western Nevada, water years (*A*) 2010 and (*B*) 2011. When present, the contribution of silt to total bedload mass was generally less than 0.1 percent.

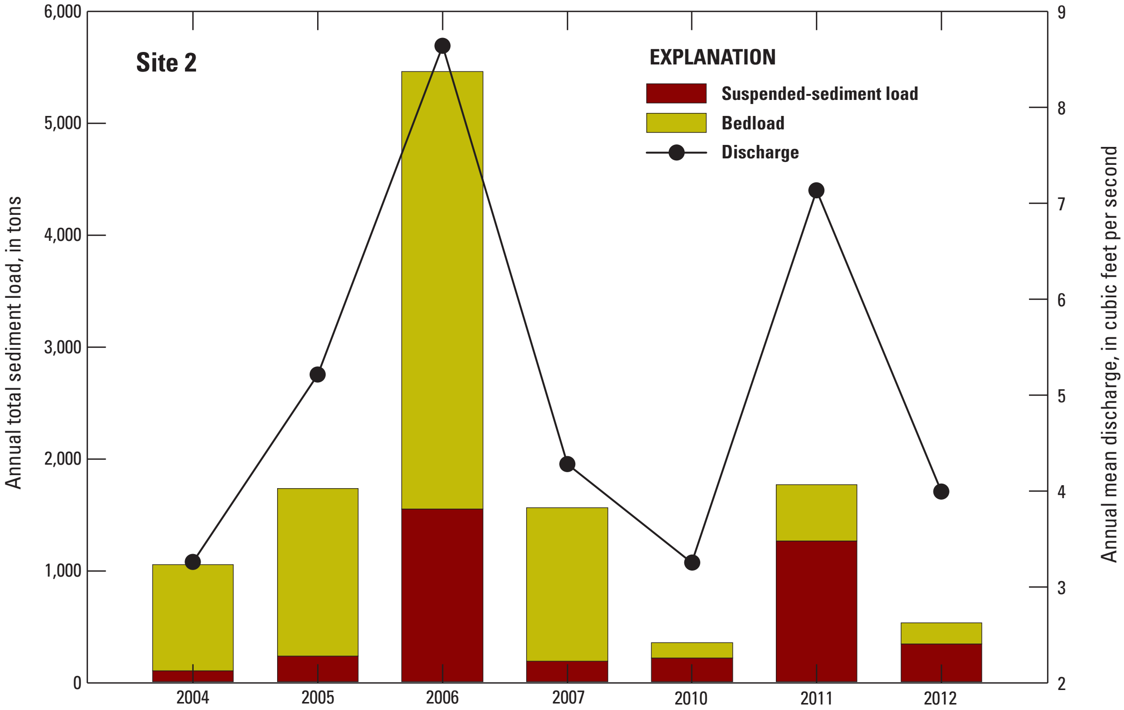

Figure 19. Relation between annual mean creek discharge and annual total sediment load for site 2, Clear Creek near Carson City, western Nevada (USGS streamgage 10310500).

Table 5. Estimated annual suspended-sediment loads, annual bedload, total sediment load, and total sediment yield for site 2, Clear Creek near Carson City, western Nevada (USGS streamgage 10310500).

[**Abbreviations:** ft^3/s, cubic feet per second; (ton/mi^2)/yr, tons per square mile per year]

Water year	Annual					Average annual total sediment yield [(ton/mi^2)/yr]
	Mean discharge (ft^3/s)	Total discharge (ft^3/s)	Suspended-sediment load (tons)	Bedload (tons)	Total sediment load (tons)	
2004	3.26	1,192.6	106	947	1,053	68
2005	5.21	1,642.6	235	1,502	1,737	112
2006	8.64	3,153.6	1,551	3,909	5,460	352
2007	4.28	1,562.0	189	1,372	1,561	101
2010	3.25	1,187.5	220	135	355	23
2011	7.13	2,601.0	1,264	504	1,768	114
2012	3.99	1,460.9	343	190	533	34

This is quite similar to the range of 40 to 234 µs/cm during 2004–07. Evaluation of chemical data collected on the same date showed that the specific conductance at site 1 was consistently lower than measurements made at sites 2 and 3. There was no significant difference in specific conductance between sites 2 and 3 (p=0.26, fig. 20). Cation concentrations, including calcium, sodium, magnesium, and potassium concentrations increased in Clear Creek from upstream to downstream, which is consistent with the increasing specific conductance (appendix 3).

At site 1, specific conductance was lower when discharge was higher (fig. 21*A*), which is to be expected in natural drainage basins where increased runoff dilutes chemical concentrations. Specific conductance was lower in the 2010–12 samples at discharges less than 1 ft^3/s than in the 2004–07 samples (fig. 21*A*). The steeper trend line slope associated with the 2004–07 dataset suggests that discharge had a greater influence on specific conductance during that time than during 2010–12. The decrease in specific conductance during 2010–12 suggests that a previous source of chemical load may have been removed from the upper drainage basin. Although observations are based on a limited dataset, most cation concentrations, including calcium and sodium, decreased with increased discharge at site 1; however, manganese increased with discharge (fig. 22*A*). Concentrations of cations generally were slightly higher in the current study than during 2004–07 (fig. 22*A*).

Specific conductance in samples collected from sites 2 and 3 did not appear to be influenced by Clear Creek discharge (figs. 21*B*–21*C*). This lack of change in specific conductance with discharge suggests a constant source(s) of chemical load in lower reaches of Clear Creek. Sodium, manganese, and chloride concentrations each indicate an increase in concentration with discharge at site 2 (fig. 22*B*). Seiler and Wood (2009) suggested the larger contributing area to the lower Clear Creek reaches, geology, and seasonal application of road salt to adjacent roads was contributing to the dissolved chemical loads. Road salt utilized by NDOT consist of a sodium chloride brine and sand (Eric Young, NDOT, written commun., February 23, 2014). Sodium and chloride concentrations measured at sites 2 and 3 were high from November to March (appendix 3). Concentrations of iron (p=0.03) were significantly higher in samples collected at site 3 in 2010–12 than in 2004–07 (fig. 22*C*).

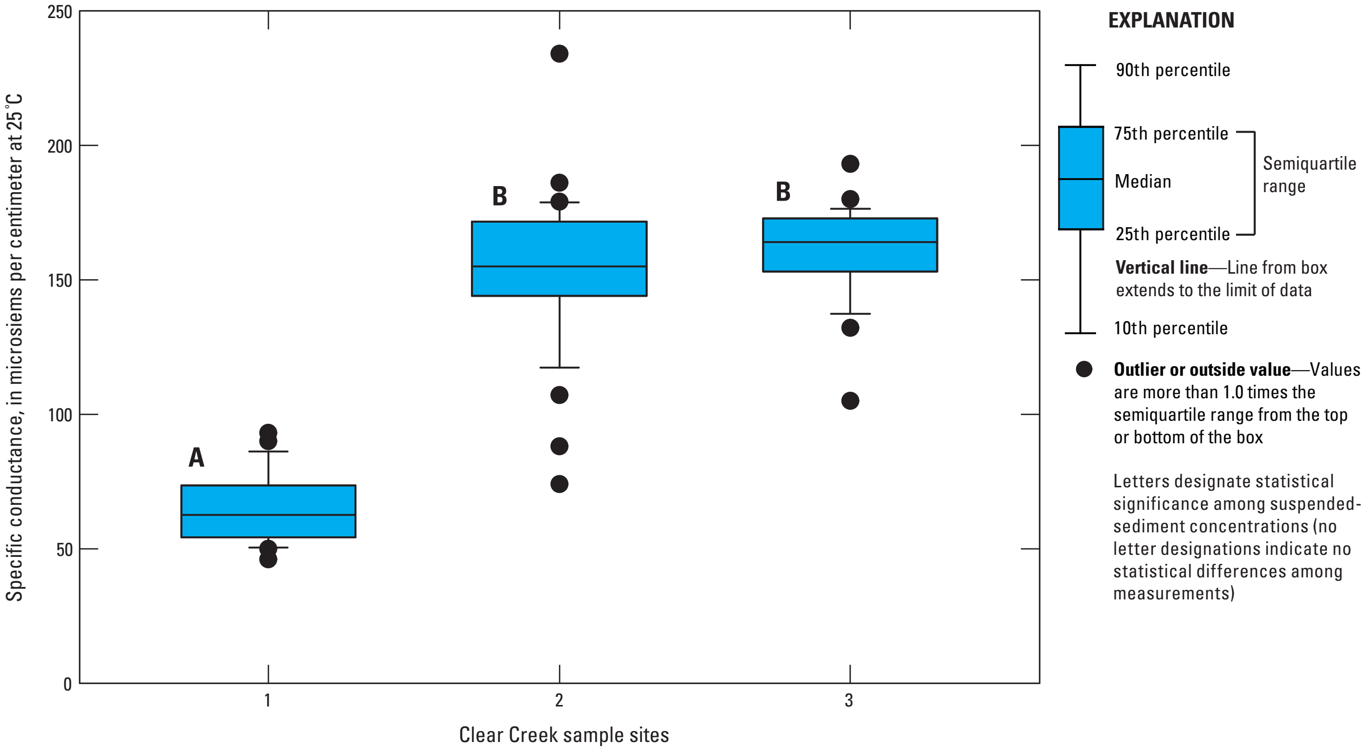

Figure 20. Range of specific conductance measured at all three Clear Creek sampling sites, western Nevada, water years 2010–12.

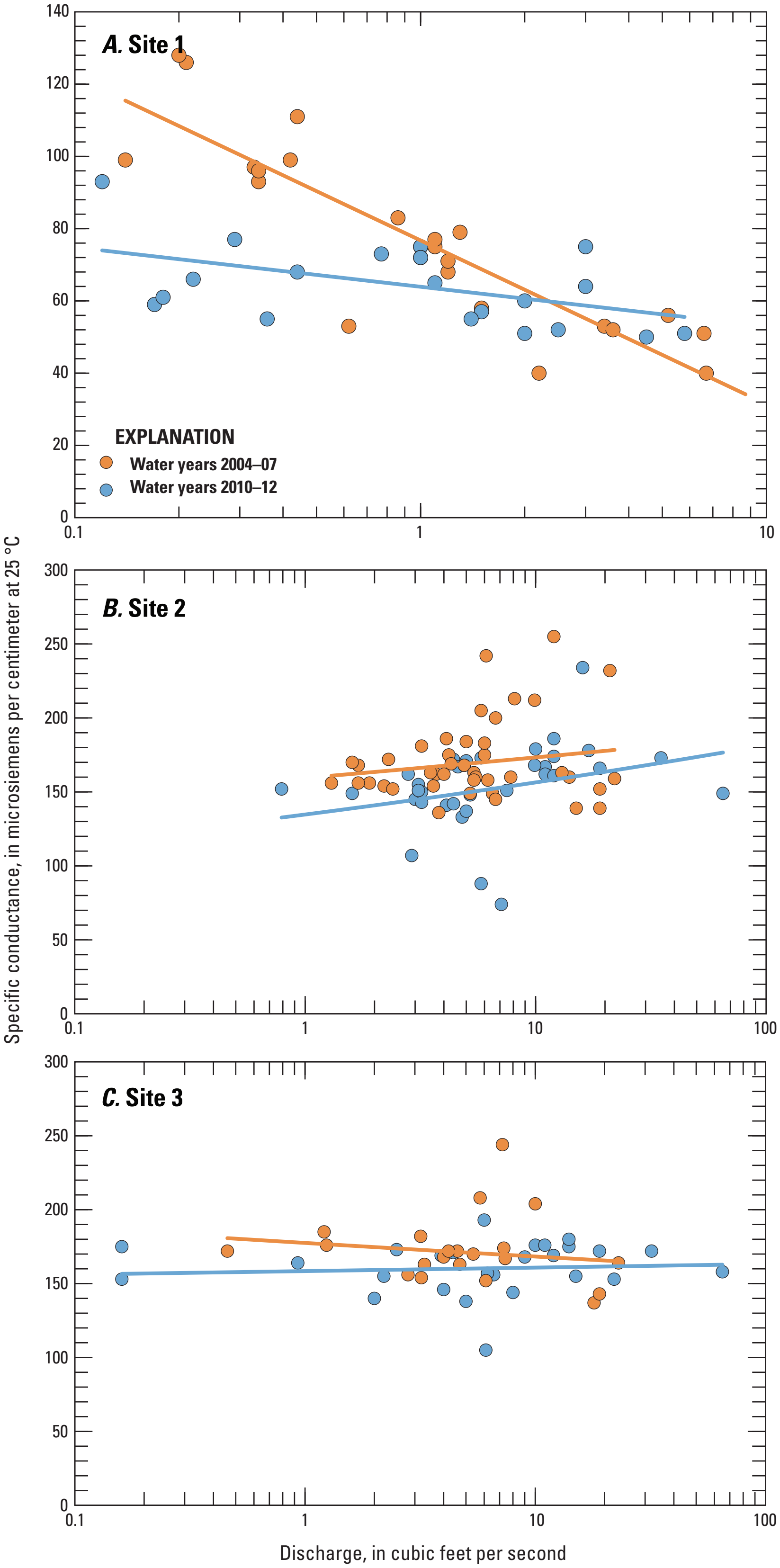

Figure 21. Relation between discharge and specific conductance at (*A*) site 1, (*B*) site 2, and (*C*) site 3, Clear Creek, western Nevada, water years 2004–07 and 2010–12.

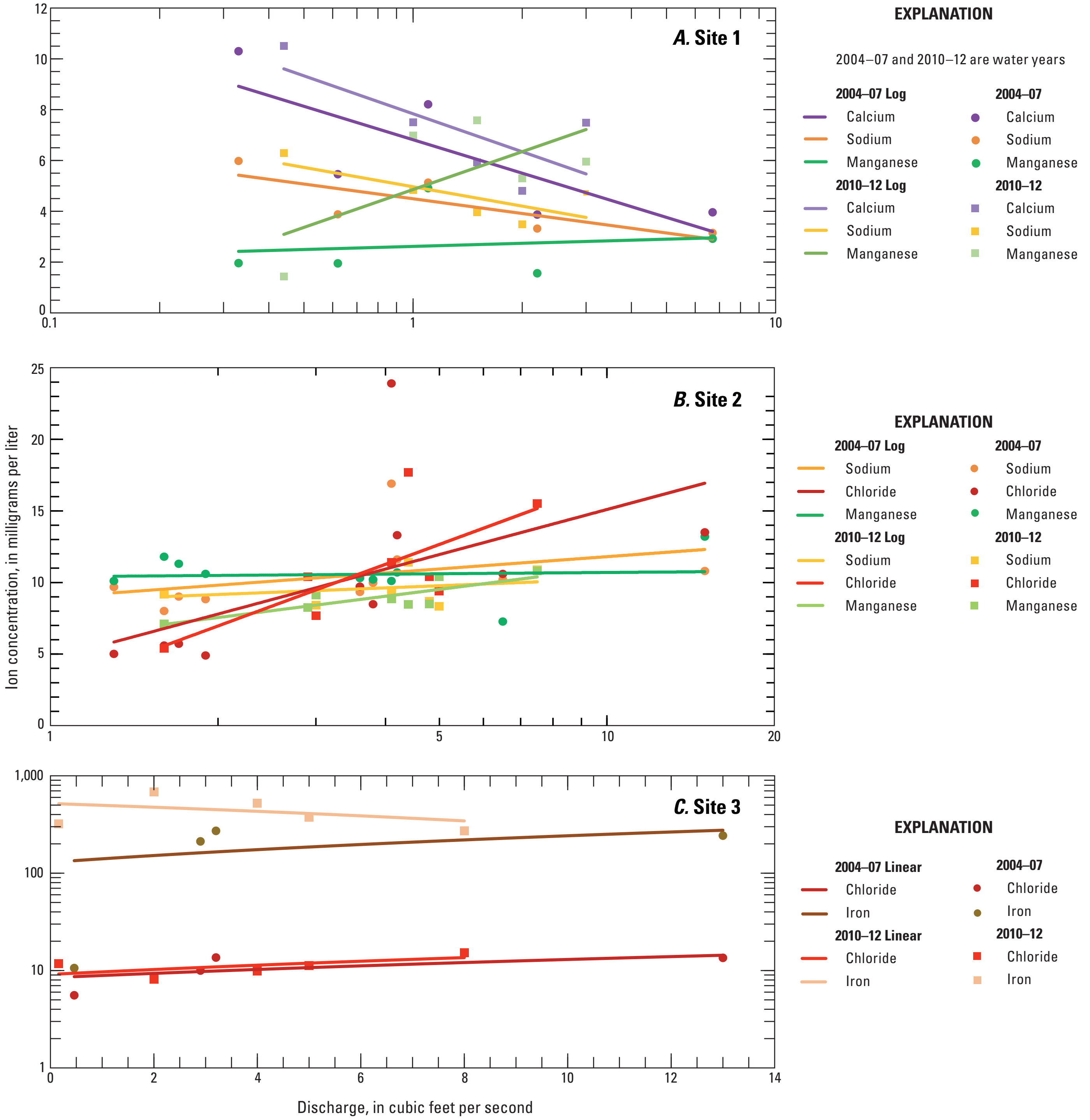

Figure 22. Relation between discharge and dissolved calcium, sodium, chloride, manganese, and iron concentrations for (*A*) site 1, (*B*) site 2, and (*C*) site 3 for Clear Creek, western Nevada, water years 2004–07 and 2010–12.

Summary and Conclusions

Clear Creek is a small alpine stream that drains the eastern Sierra Nevada near Lake Tahoe, flows roughly parallel to the U.S. Highway 50 corridor, and ultimately discharges to the Carson River near Carson City, Nevada. It is unclear how historical and ongoing development in the drainage basin is influencing the physical and chemical characteristics of Clear Creek. In 2004, the Nevada Department of Transportation was issued a permit by the Nevada Division of Environmental Protection in response to pollutant discharge to the municipal storm water sewer system. In turn, the Nevada Department of Transportation developed a Clear Creek Storm Water Management Program and entered into a cooperative agreement with the U.S. Geological Survey to assess general water quality of Clear Creek and sediment loading within the drainage basin. The initial study of this collaborative effort during water years 2004-07 evaluated baseline conditions in Clear Creek. The evaluation included characterization of data collected from three sampling sites and is presented in Seiler and Wood (2009). The data included discharge; selected water-quality parameters; and suspended-sediment concentrations, loads, and yields for water years 2004–07. The current study builds from what was learned from Seiler and Wood (2009) and serves as a continuation of the data collection and analyses of the Clear Creek discharge and associated water-quality and sediment concentrations and loads during water years 2010–12.

The same three sites previously established by Seiler and Wood (2009) were evaluated as part of this study. Continued data collection at these three sites allowed for the comparison of current data to baseline conditions. Site 1 is ungaged and represents the headwater area of the upper drainage basin and is therefore considered a reference site; site 2 is gaged and represents the mid-drainage basin area, which includes some low-density residential areas; and site 3 is ungaged and represents the lower drainage basin area, which includes more urbanization. Discharge generally increased with distance downstream.

Clear Creek discharge is variable primarily because of the variability in snowpack in the drainage basin, which serves as the source of discharge. Generally, discharges in the creek are highest during the spring (March–May); however, rain-on-snow events can cause dramatic increases in discharge during months that do not characteristically experience high discharge. Discharge has been collected continuously at site 2 during water years 1949–62 and 1990–2012. The long-term annual mean discharge is 5.31 cubic feet per second (ft^3/s), whereas during this study, the annual mean discharge was 3.25 ft^3/s in 2010, 7.13 ft^3/s in 2011, and 3.99 ft^3/s in 2012. Discharge in Clear Creek was below monthly median levels throughout much of the current study; the exception being discharge resulting from a large snowpack and subsequent spring runoff in water year 2011. A flow-duration analysis of mean daily discharge at site 2 throughout the entire dataset (water years 1949–62 and 1990–2012) indicates low-discharge conditions (those discharges equal to or less than the 25th percentile for the creek) between 0.4 to 2.3 ft^3/s. Moderate discharge conditions were defined as mean daily discharges representing between the 25th and 75th percentiles (about 2.4 to 6.6 ft^3/s). High discharge conditions were defined as mean daily discharges equal to or exceeding the 75th percentile (6.7 ft^3/s). The minimum flow observed in Clear Creek was 0.42 ft^3/s and occurred in August 1992; to date, the maximum flow of 266 ft^3/s was observed in Clear Creek and occurred on January 2, 1997.

A flood-frequency analysis (recurrence-interval evaluation) was completed because understanding high-discharge events, flood magnitudes, and frequency helps characterize sediment movement. The analysis included 55 annual peak discharges (ranging from 5 to 266 ft^3/s) from site 2 observed between water years 1948–78 and 1989–2012 and suggested that Clear Creek has a 1 percent probability (one chance in 100 years) of reaching a 336 ft^3/s peak discharge. The two highest observed peak discharges of 266 (January 2, 1997) and 252 ft^3/s (December 31, 2005) were estimated to have an annual exceedance probabilities of 1.8 and 3.6 percent, respectively. The annual peak discharges for 2010 (13 ft^3/s), 2011 (87 ft^3/s), and 2012 (35 ft^3/s), were all greater than the 10 percent annual exceedance probability.

Sediment samples collected at the three Clear Creek sites during periods of base flow, storm events, and the snowmelt-runoff period were analyzed for sediment load (suspended-sediment concentration and bedload), sand break, particle-size distribution, and specific water-chemistry constituents. Suspended-sediment concentrations at each of the three Clear Creek sampling sites were within the same range as samples collected during 2004–07, suggesting that concentrations are within what can be considered baseline. Generally, suspended-sediment concentrations were higher in the lower reaches of Clear Creek (sites 2 and 3) than in the upper drainage basin (site 1); however, during 2010–12 there was no statistical difference between suspended-sediment concentrations at sites 1 and 3.

Comparison of data collected from 2004 to 2007 to those from 2010 to 2012 showed that suspended-sediment concentration and associated discharge measurements were statistically similar. During water years 2010–12 at sites 1 and 3, there was no statistical difference among concentrations measured during high, moderate, or low discharges; although concentrations were elevated at discharges greater than 5.2 ft^3/s at site 1 and 19 ft^3/s at site 3. There was no difference between suspended-sediment concentrations measured at site 2 during moderate and low discharges; however, suspended-sediment concentrations were statistically significantly higher during discharges greater than 16 ft^3/s. Sediment deposition has been previously documented to occur upstream of site 3, which may explain, at least in part, why a strong difference in suspended-sediment concentrations were not measured under varying discharge at this site.

Sand break, the percentage by weight of a suspended-sediment sample finer than 0.0625 millimeters, represents the division between sand and silt and was analyzed for in a subset of the suspended-sediment samples. Silt appeared to comprise most of the suspended sediment transported in Clear Creek during water years 2010–12 and a general increase in the silt content was observed with distance downstream. Comparison of the percentages of silt in samples collected between 2004–07 to those collected between 2010–12 indicates a possible increase in median silt-size (percentage by weight).

During this study, suspended-sediment loads ranged from 0 to 0.52 ton/d at site 1, 0.01 to 40 ton/d at site 2, and 0 to 13 ton/d at site 3. Suspended-sediment loads are almost always lower at sites 1 and 3 than at site 2, indicating that sediment is being mobilized upstream of site 2. The single highest suspended-sediment load (86 ton/d) was observed at site 2 during a precipitation event that occurred in late December 2005 when discharge reached 110 ft^3/s. A logarithm transformation analysis was performed to look for a relation between suspended-sediment loads and discharge between the 2004–07 and 2010–12 datasets. Results indicated no significant difference between the two study periods at any of the sites.

During both studies (water years 2004–07 and 2010–12), suspended-sediment loads associated with high discharge at all three sites were statistically greater than loads associated with low discharge. Suspended-sediment loads associated with discharge greater than about 2.2 ft^3/s were significantly higher at site 1. Suspended-sediment loads at sites 2 and 3 are generally similar during high and moderate discharges; however, significantly lower during low discharge. Suspended-sediment loads generally were significantly higher at discharges greater than 5.5 and 3.2 ft^3/s at sites 2 and 3, respectively.

Bedload was only measured at discharges greater than or equal to 5.8 ft^3/s at site 1, 2.8 ft^3/s at site 2, and 1.5 ft^3/s at site 3 during the current study (water years 2010–12) and was comprised of mostly sand-sized sediment with very little silt. Gravel-sized sediment contributed to the bedload composition only when discharge equaled or exceeded 2.8 ft^3/s at site 2 and 1.5 ft^3/s at site 3. A comparison of samples collected on the same day at sites 2 and 3 indicates no difference in bedload between the two sites on that day. For a given discharge at site 2, there was less bedload sediment during 2010–12 than during 2004–07. Although uncertain, explanations for lower bedload could include changes in the drainage basin affecting bedload source material and changes in discharge affecting bedload transport.

Total sediment loads (combined suspended-sediment load and bedload) are a function of stream discharge and, therefore, can vary substantially by year. Annual sediment loads (a relation between discharge and total sediment loads) were computed for site 2 using daily discharge and ranged from 1,053 to 5,460 tons during 2004–07 and from 355 to 1,768 tons during 2010–12. The significant decrease in total annual sediment loads between the datasets is likely attributed to the decreased mean daily discharge measured at site 2 during 2010–12.

During this study, the general water chemistry characteristics measured in Clear Creek (water temperature, pH, and specific conductance) were similar to those observed during water years 2004–07. Specific conductance values were consistently lower at site 1, reflecting its headwater location, while no significant difference was measured in specific conductance values between sites 2 and 3. As discharge increases, specific conductance was observed to generally remain constant at sites 2 and 3, which suggests that a constant source(s) of chemical load in lower reaches of Clear Creek is present. Clear Creek water samples were collected and analyzed for selected major inorganic ions, trace metals, nutrients, and pesticides during this study. Major ion chemistry indicated notable decreases in concentrations of calcium and sodium with discharge at site 1, but increases in concentrations with discharge at site 2 of sodium, manganese, and chloride. Clear Creek continues to represent a dilute calcium/sodium bicarbonate type water with low nutrient concentrations, and no detections of pesticides, as was described in the initial study during water years 2004–07.

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Appendix 1. Streamflow, Field Measurements, and Suspended-Sediment Analyses for Samples Collected at Clear Creek Sites, Western Nevada, Water Years 2010–12

[Location of sampling sites are shown in figure 1. USGS site ID given in parentheses after site name. **Abbreviations:** ºC, degrees Celsius; ft³/s, cubic feet per second; hhmm, 24-hour time format in 2-digit hour and 2-digit minute; mg/L, milligram per liter; µS/cm, microsiemens per centimeter; %, percent; ton/d, ton per day; –, no data available]

Date	Time (hhmm)	Field measurements				Suspended sediment		
		Discharge (ft^3/s)	Water temperature (ºC)	pH	Specific conductance (µS/cm)	Sampled concentration (mg/L)	Sand break (%)	Transport rate (ton/d)
Site 1. Clear Creek above Highway 50, near Spooner Summit (10310485)								
10-13-09	1245	0.44	6	–	–	19	64	0.02
10-14-09	0745	0.46	8.5	–	–	10	44	0.01
11-23-09	1019	0.44	4	7.9	68	5	47	0.01
01-13-10	0935	0.36	2.9	–	55	6	76	0.01
02-25-10	1110	0.18	2.4	–	61	4	50	0
03-11-10	1050	–	1.2	7.8	90	–	–	–
04-22-10	1430	0.77	2.4	7.1	73	3	63	0.01
05-27-10	1015	1.4	4.2	7.1	55	1	75	0
06-11-10	1440	–	7.6	7.4	46	–	–	–
07-20-10	1300	0.17	12.8	7.7	59	6	58	0
08-19-10	1150	0.12	11	8.1	93	1	67	0
10-05-10	1209	1.1	6.7	7.7	65	21	65	0.06
10-18-10	1315	0.29	7.2	7.4	77	29	76	0.02
11-19-10	1024	0.22	3.3	7.4	66	1	–	0
03-05-11	1510	2	2	7.7	60	3	–	0.02
04-01-11	1030	3	3	7.7	75	6	–	0.05
05-27-11	1300	2.5	5	7.5	52	2	–	0.01
06-05-11	0830	4.5	4.5	7.5	50	13	–	0.16
06-06-11	0750	5.8	3	7.6	51	33	–	0.52
07-29-11	1045	2	10.5	7.7	51	<0.5	–	<0.003
08-29-11	1100	1.5	10.5	7.8	57	2	–	0.01
11-09-11	1115	3	2.5	6.9	64	1	–	0.01
01-23-12	1320	1	1	7.1	72	1	–	0
03-16-12	1155	1	3.5	7.6	75	2	–	0.01
Site 2. Clear Creek near Carson City (10310500)								
10-13-09	1450	3.6	11	–	–	183	76	1.8
10-14-09	0915	5.8	10.5	–	–	40	84	0.63
11-23-09	1330	2.9	3.6	–	107	–	–	–
01-13-10	1115	5.2	3.4	–	148	15	68	0.21
02-25-10	1150	4.6	4.2	–	167	9	59	0.11
03-11-10	1250	4.4	3.5	8.1	172	–	–	–
04-22-10	1312	5.8	4.5	–	173	–	–	–
04-22-10	1340	5.8	–	–	–	11	77	0.17
05-27-10	1130	4.4	7.4	–	142	7	84	0.08
06-11-10	1305	4.1	10.1	8.1	141	–	–	–
07-20-10	1100	1.7	–	–	–	8	86	0.04

Appendix 1. Streamflow, field measurements, and suspended-sediment analyses for samples collected at Clear Creek sites, western Nevada, water years 2010–12.—Continued

[Location of sampling sites are shown in figure 1. USGS site ID given in parentheses after site name. **Abbreviations:** ºC, degrees Celsius; ft^3/s, cubic feet per second; hhmm, 24-hour time format in 2-digit hour and 2-digit minute; mg/L, milligram per liter; µS/cm, microsiemens per centimeter; %, percent; ton/d, ton per day; –, no data available]

Date	Time (hhmm)	Field measurements				Suspended sediment		
		Discharge (ft^3/s)	Water temperature (ºC)	pH	Specific conductance (µS/cm)	Sampled concentration (mg/L)	Sand break (%)	Transport rate (ton/d)
Site 2. Clear Creek near Carson City (10310500)—Continued								
08-19-10	1425	0.79	13.8	–	152	5	88	0.01
09-30-10	1225	1.6	11.8	8.1	149	–	–	–
10-04-10	0855	3.1	11.2	8	151	42	82	0.35
10-05-10	1107	7.1	9.3	7.5	74	104	87	2
10-06-10	0928	3.2	8.3	7.9	150	22	78	0.19
10-07-10	1042	3.2	9.5	8	143	43	87	0.37
10-18-10	1015	3.1	9.5	8	155	114	90	0.95
10-25-10	1135	5	7.9	8	171	55	75	0.74
11-19-10	1130	2.8	6.1	8	162	12	–	0.09
12-14-10	1030	6.4	–	–	–	526	60	9.1
12-14-10	1328	12	5.3	7.8	161	348	71	11
12-19-10	1307	12	2.8	7.9	186	58	–	1.9
03-06-11	1645	5.8	5.5	7.9	88	38	–	0.6
03-07-11	0850	9.9	2.5	7.6	168	78	–	2.1
03-14-11	0855	19	3	7.6	166	307	30	16
03-16-11	0755	65	3	7.6	149	229	–	40
04-01-11	0845	16	4.5	7.7	234	110	–	4.8
05-27-11	1400	11	10	7.9	162	40	–	1.2
06-05-11	0945	12	8.5	7.9	174	224	–	7.3
06-06-11	0943	35	6.5	7.9	173	273	42	26
07-29-11	1220	5	14	7.9	137	13	–	0.18
08-29-11	1250	3	13	8.2	145	9	–	0.07
11-09-11	1300	4.8	3	7.2	133	4	–	0.05
01-21-12	0725	17	2	7	178	356	–	16
01-23-12	1010	7.5	1.5	7.1	151	19	–	0.38
03-16-12	1255	11	6.5	7.2	167	140	–	4
03-17-12	0955	10	3.5	7.3	179	52	–	1.4
Site 3. Clear Creek at Fuji Park, at Carson City (10310518)								
10-13-09	1555	1.5	11	–	–	–	–	–
10-14-09	1020	3.5	9	–	–	21	87	0.2
11-23-09	1500	–	4.2	7.7	132	–	–	–
11-23-09	1510	–	–	–	–	3	73	–
01-13-10	1315	6.2	4.2	–	157	8	89	0.13
02-25-10	1500	4.4	5.5	7.7	171	15	89	0.18
03-11-10	1405	–	5.6	7.9	164	–	–	–
04-22-10	1143	6.6	3.8	7.5	156	15	86	0.27
05-27-10	1350	3.9	9.6	7.6	169	6	79	0.06
06-11-10	1205	0.16	11.7	7.8	153		–	–
07-20-10	1215	0.16	17.2	7.9	175	1	75	0.000
08-19-10	1400	0.93	16.5	7.8	164	1	67	0.002
10-05-10	0955	6.1	10	7.2	105	40	80	0.66
10-18-10	1150	2.2	10.6	7.5	155	102	96	0.61
11-19-10	1212	2.5	6.7	7.5	173	1	–	0.007
12-14-10	1437	14	5.6	7.3	180	40	70	1.51

Appendix 1. Streamflow, field measurements, and suspended-sediment analyses for samples collected at Clear Creek sites, western Nevada, water years 2010–12.—Continued

[Location of sampling sites are shown in figure 1. USGS site ID given in parentheses after site name. **Abbreviations:** ºC, degrees Celsius; ft^3/s, cubic feet per second; hhmm, 24-hour time format in 2-digit hour and 2-digit minute; mg/L, milligram per liter; µS/cm, microsiemens per centimeter; %, percent; ton/d, ton per day; –, no data available]

Date	Time (hhmm)	Field measurements				Suspended sediment		
		Discharge (ft^3/s)	Water temperature (ºC)	pH	Specific conductance (µS/cm)	Sampled concentration (mg/L)	Sand break (%)	Transport rate (ton/d)
Site 3. Clear Creek at Fuji Park, at Carson City (10310518)								
03-05-11	1705	6	6	7.9	193	2	–	0.032
03-07-11	0905	12	3	7.7	169	17	–	0.53
03-14-11	1000	22	3.5	7.6	153	55	90	3.3
03-16-11	0845	65	4	7.7	158	74	90	13
04-01-11	0910	15	6	7.9	155	5	–	0.2
05-27-11	1430	9	10	7.8	168	10	–	0.24
06-05-11	1018	14	9.5	7.6	175	12	–	0.46
06-06-11	1018	32	7	7.7	172	89	94	7.7
07-29-11	1350	4	17	7.6	146	17	–	0.18
08-29-11	1440	2	16.5	8	140	8	–	0.043
11-09-11	1405	5	3.5	7.2	138	3	–	0.04
01-21-12	0840	19	2	7	172	123	–	6.3
01-23-12	1200	8	2	7	144	12	–	0.26
03-16-12	1350	11	8	7.1	176	24	–	0.71
03-17-12	1105	10	5	7.3	176	11	–	0.3

Appendix 2. Bedload-Sediment Data for Samples Collected at Clear Creek Sites, Nevada, Water Years 2010–12

[USGS site ID given in parentheses after the site name. **Silt-sized**, sediment particles less than 0.0625 mm in diameter. **Sand sized**, particles greater than 0.0625 mm and less than or equal to 2 mm in diameter. **Gravel sized**, particles with a diameter greater than 2 mm; **Abbreviations:** hhmm, 24-hour time format in 2-digit hour and 2-digit minute; ft^3/s, cubic feet per second; mm, millimeters. t/d, tons per day; –, data not available]

Date	Time (hhmm)	Discharge (ft^3/s)	Bedload sediment, total sample mass, dry weight	Silt-sized bedload fraction	Sand-sized bedload fraction	Gravel-sized bedload fraction	Bedload sediment transport rate (t/d)
			(grams)				
Site 1. Clear Creek above Highway 50, near Spooner Summit (10310485)							
08-25-04	1000	0.34	10.7	0.2	8.9	1.6	0.03
06-06-11	0800	5.8	40.6	0.20	31.3	9.10	0.74
Site 2. Clear Creek near Carson City (10310500)							
10-13-09	1450	3.6	43.6	0.1	43.5	0	0.33
10-14-09	0910	5.8	21.0	0	21.0	0	0.16
11-23-09	1340	2.9	81.2	0	79.4	1.8	0.62
01-13-10	1115	5.2	103.2	0	78.3	24.9	0.79
02-25-10	1150	4.6	73.8	0	66.2	7.6	0.62
04-22-10	1312	5.8	11.5	0	9.3	2.2	0.18
04-22-10	1328	–	87.6	0	72.5	15.1	1.33
10-05-10	1107	7.1	9.8	0.1	9.6	0.1	0.17
10-06-10	0928	3.2	39.4	0.1	9.8	0	0.25
10-18-10	1030	3	17.8	0.1	17.7	0	0.11
10-25-10	1135	5	33.1	0.1	31.8	1.2	0.21
11-19-10	1130	2.8	10.6	0	10.3	0.3	0.07
12-14-10	1328	12	223.1	0.2	215.1	7.8	1.65
12-19-10	1307	12	62.4	0.1	57.8	4.5	0.92
03-14-11	0855	19	375.9	0.1	181.7	194.1	9.55
03-16-11	0755	65	248.1	0.1	209.2	38.8	7.88
06-05-11	0945	12	830.9	0.1	202.8	628.0	14.07
06-06-11	0943	35	335.5	0.1	282.9	52.5	9.23
01-21-12	0725	17	116.0	0.1	111.9	4.0	2.36
03-16-12	1255	11	171.6	0.1	101.1	14.8	2.54
03-17-12	0955	10	79.6	0	78.5	1.1	1.18
Site 3. Clear Creek at Fuji Park, at Carson City (10310518)							
02-25-04	1515	7.3	48.8	0.1	39.1	9.6	0.49
05-28-04	0850	2.8	40.4	0.2	29.9	10.2	0.43
09-07-04	1300	0.46	8.2	0.0	6.6	1.6	0.03
10-13-09	1555	1.5	26.7	0	25.2	1.5	0.22
10-14-09	1020	3.5	142.0	0	139.9	2.1	0.98
11-23-09	1510	–	66.6	0	61.6	5.0	0.68
01-13-10	1315	6.2	513.0	0	122.1	390.9	4.65
02-25-10	1500	4.4	106.4	0	104.1	2.3	0.85
04-22-10	1120	6.6	1.4	0	1.2	0.2	0.03
04-22-10	1143	6.6	127.8	0	102.0	25.8	2.32
05-27-10	1350	3.9	1.4	0	1.4	0	0.03
10-05-10	1015	6.1	3.9	0	3.9	0	0.07
12-14-10	1437	14	55.5	0.1	52.5	2.9	0.51
03-16-11	0845	65	288.1	0.2	135.7	152.2	4.06

Appendix 3. Water-Quality Data for Samples Collected at Clear Creek Sites, Nevada, Water Years 2010–12

[Location of sampling sites are shown in figure 1. USGS site ID given in parentheses after site name. **Abbreviations:** hhmm, 24-hour time format in 2-digit hour and 2-digit minute; mg/L, milligram per liter; µg/L, microgram per liter; E, estimated; <, less than; –, no data available]

Date	Time (hhmm)	Dissolved solids	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulfate	Fluoride	Silica	Iron	Manganese	Boron
		(mg/L)									(µg/L)		
Site 1. Clear Creek above Highway 50, near Spooner Summit (10310485)													
11-23-09	1019	77	10.5	2.35	6.29	1.69	0.55	0.69	0.06E	23.2	42	1.4	–
03-11-10	1050	–	9.81	2.26	5.89	1.62	0.55	0.73	<0.08	25.3	52	1.9	E 2
06-11-10	1440	37	4.5	1.06	3.68	0.98	0.31	0.33	–	18.3	76	3.1	E 2
07-29-11	1045	42	4.81	1.17	3.48	0.85	0.2	0.23	<0.04	20.5	144	5.3	< 3
08-29-11	1100	53	5.92	1.39	3.97	1.06	0.24	0.35	<0.04	21.4	185	7.6	< 3
11-09-11	1115	62	7.49	1.8	4.73	1.28	0.54	0.43	<0.04	23.7	120	6	< 3
01-23-12	1320	61	7.5	1.88	4.84	1.61	0.79	0.49	0.06	23	108	7	3
Site 2. Clear Creek near Carson City (10310500)													
11-23-09	1330	121	18.6	3.03	10.4	2.03	10.4	1.11	0.08	21.1	98	8.3	–
03-11-10	1250	137	18.1	3.27	11.4	2.11	17.7	1.69	0.05E	22.4	97	8.5	4
06-11-10	1305	103	15.2	2.57	9.43	1.64	11.4	0.78	0.06E	21	148	8.9	4
07-29-11	1225	123	19.5	2.96	9.18	2.02	5.38	0.98	0.09	20.6	114	7.1	7
08-29-11	1220	90	13.7	2.7	8.32	1.66	9.39	0.63	0.07	23.1	296	10.4	5
11-09-11	1250	102	15.2	2.84	8.42	1.79	7.67	0.86	0.04	22.1	277	9.1	4
01-23-12	1300	102	16.8	3.17	8.69	1.73	10.4	0.57	0.06	23.7	139	8.5	4
Site 3. Clear Creek at Fuji Park, at Carson City (10310518)													
11-23-09	1500	125	18.8	3.15	11	2.12	11.5	1.1	0.08	21.8	244	15.2	–
03-11-10	1405	139	18.4	3.34	11.7	2.06	18.1	1.62	0.05E	22.7	225	20.7	4
06-11-10	1205	109	15.6	2.88	9.68	1.93	11.8	0.74	0.07E	21.9	322	33.4	5
07-29-11	1350	111	14.6	2.9	8.79	1.7	9.92	0.66	0.08	23.8	522	29.3	5
08-29-11	1440	102	16.4	3.13	8.93	1.87	8.17	0.54	0.05	23.4	686	28.1	3
11-09-11	1405	100	16.7	3.28	9.57	1.9	11.2	0.55	0.06	24.2	375	32.9	4
01-23-12	1200	91	13.9	2.87	11	2.81	15.2	1.1	0.09	17.5	272	44.5	8

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