



Water Quality Monitoring for the Mancos River in Mesa Verde National Park

2011 Summary Report

Natural Resource Data Series NPS/SCPN/NRDS—2013/567



ON THE COVER
Manco River, Mesa Verde NP
Photograph by SCPN

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September 2013

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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Funding for the SCPN water resources field crew was provided to Northern Arizona University by the National Park Service through Colorado Plateau CESU Agreement H1200090005 (Tasks NAU-331). Funding for water quality sample analysis was provided by the National Park Service to the United States Geological Survey through Interagency Agreement # F2121090111.

The corresponding author and project manager for this project is Stephen Monroe (Stephen_Monroe@nps.gov). Other contributions were made by the SCPN staff. Melissa Dyer is the Water Resources Crew Leader for the project. The 2011 crew consisted of Kelly Lawrence, Stacy Stumpf and Tim Sullivan. SCPN staff provided support for the project.

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Please cite this publication as:

Dyer, Melissa, and Stephen. A. Monroe. 2013. Water quality monitoring for the Mancos River in Mesa Verde National Park: 2011 summary report. Natural Resource Data Series NPS/SCPN/NRDS—2013/567. National Park Service, Fort Collins, Colorado.

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1 Introduction

The National Park Service Inventory and Monitoring Program was designed to determine the current status and monitor long-term trends in the condition of park natural resources, providing park managers with a scientific foundation for making decisions and working with other agencies and the public to protect park ecosystems. Hydrologic vital signs are the fundamental components defining overall riparian and aquatic ecosystem integrity. The Southern Colorado Plateau Network (SCPN) has identified 7 vital signs pertaining to riparian and spring ecosystems: 1) stream water quality, 2) aquatic macroinvertebrates, 3) stream flow and depth to groundwater, 4) spring water quality, 5) fluvial geomorphology, 6) riparian vegetation, composition, and structure, and 7) spring ecosystems. These vital signs are closely related and are all included in the Vital Signs Monitoring Plan for the Southern Colorado Plateau Network (Thomas et al. 2006). The context and ecological significance of these vital signs are further explained in Scott et al. (2005). In this report we focus on stream water quality.

Specific objectives of stream water quality monitoring for the SCPN parks are

- Determine status and trends in selected core water quality parameters (water temperature, pH, specific conductivity, dissolved oxygen, turbidity and discharge) at selected sites in priority streams within SCPN parks.
- Determine status and trends of selected water quality constituents, including bacteria, nutrients, major elements, and trace metals at selected sites in priority streams within SCPN parks.
- Compare water quality data against state standards for chronic exceedances. Multiple exceedances in a year typically indicate non-compliance.

1.1 Selecting potential water quality monitoring sites

We targeted SCPN streams and springs with potential for water quality monitoring by reviewing (1) water quality data inventory and analysis reports prepared by the Water Resources Division (WRD) of the National Park Service (NPS), (2) a USGS summary and review of available water quality data from streams in SCPN parks (Brown 2008), (3) data collected during a Level 1 water quality inventory of streams in SCPN parks (Macy and Monroe 2006), and (4) results of water quality planning meetings with park staff.

SCPN water bodies were selected for water quality monitoring based on the following criteria:

- 303(d) listed waters¹ - where previous sampling indicates one or more parameters regularly approach or exceed established water quality standards or recommended levels
- waters with demonstrated threat levels – where an analysis of existing data indicate that measured conditions regularly approach or exceed standards or recommended levels, but where the frequency of exceedances or the quality of the database do not support a 303(d) listing
- pristine waters – where there is no direct impact of human activities (provides baseline data)
- ecological significance – presence of unique species or species of concern
- waters of management concern – where past sampling may not indicate constituent values of concern, but where anthropogenic activities indicate that contamination is a significant threat
- historic data – waters identified as important, for which substantial historic water quality data is available
- data gaps – waters identified as important, but where little or no water quality information exists

Water quality monitoring sites are located whenever possible where a history of water quality data collection exists, and are co-located with SCPN aquatic macroinvertebrate monitoring sites whenever possible. NPS core water quality data and water quality samples are collected at regular intervals throughout the year. Diurnal variation in NPS core water quality parameters are characterized by deploying a multi-parameter sonde to collect

¹ Under section 303(d) of the Clean Water Act, states, territories, and authorized tribes are required to develop lists of impaired waters— waters that are too polluted or otherwise degraded to meet the water quality standards set by states, territories, or authorized tribes (EPA 2011).

data for as many days as possible during base flows. Water quality samples are analyzed by SCPN staff and by a qualified contract laboratory.

1.2 Water quality monitoring at Mesa Verde National Park

The Mancos River is a perennial stream flowing from Colorado's La Plata Mountains to its confluence with the San Juan River in northwestern New Mexico. Approximately four miles of the river flow along the eastern boundary of Mesa Verde National Park (MEVE). Upstream from the park, Jackson Gulch Dam diverts water from the Mancos River; both the dam and numerous diversions in the Mancos Valley reduce the amount of Mancos River flow that reaches MEVE (Colorado Water Trust 2011). In August of 2000, the NPS, in cooperation with the United States Geological Survey (USGS), installed a streamflow gaging station on the Mancos River within MEVE (Figure 1).

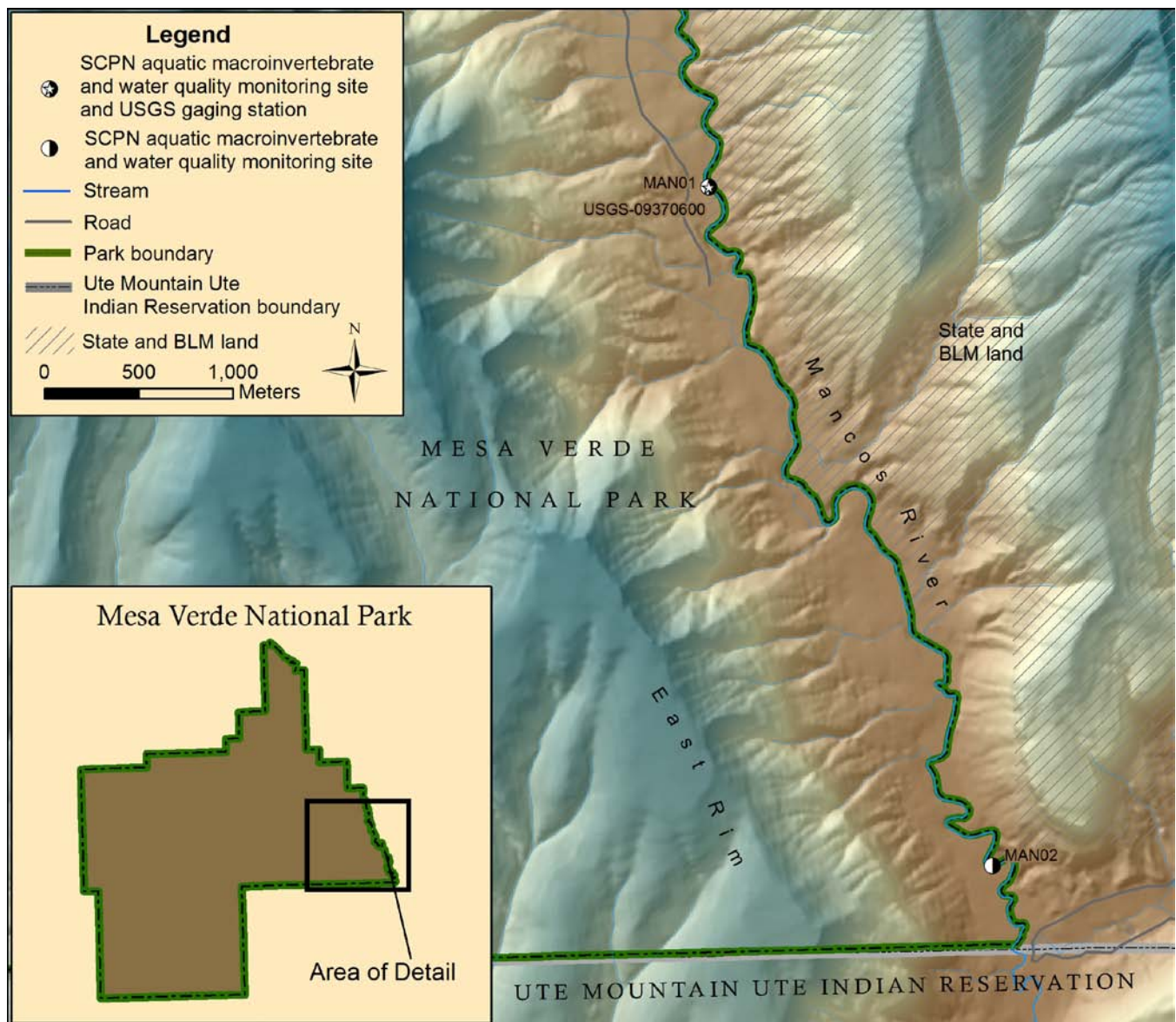


Figure 1. Map of the Mancos River, Mesa Verde NP, Colorado, with the location of Southern Colorado Plateau Network's aquatic macroinvertebrate and water quality monitoring sites MAN01 and MAN02 on the Mancos River, visited in 2011.

Water quality concerns within the park include insecticide, algicide, and herbicide applications (Brown 2008). Adjacent agriculture and sewage-treatment facilities have been sources of nutrient and bacterial contamination

(Thomas et al. 2006). Irrigation practices along the Mancos River and its tributaries are suspected to have contributed to elevated salinity levels (Yochum 2004). Drought and wildfire have also affected the river. In 2000, a high-intensity fire burned portions of the watershed in MEVE; fire retardant drops during the fire resulted in fish kills (San Miguel, G., Natural Resource Manager, Mesa Verde NP, personal communication, 28 July 2011).

Data documenting water quality conditions in the Mancos River are sparse. The most recent samples collected in the park were part of a Level 1 water quality inventory of water bodies in SCPN parks completed by the USGS in 2005 and 2006 (Macy and Monroe 2006). An assessment of the functional condition of the Mancos River conducted in 2006 found high concentrations of algal blooms, probably caused by high solar exposure, combined with a wide shallow channel near MAN01, and a possible indicator of poor water quality (Stacey 2007).

In 2010, SCPN implemented water quality monitoring on the Mancos River in MEVE. SCPN water quality monitoring occurs at two sites on the Mancos River in MEVE:

- *Mancos River at Gage* (MEVEMAN01), identified in this report as MAN01 (appendix A), was established in 2010 as SCPN's primary water quality monitoring site. The site is co-located with a SCPN aquatic macroinvertebrate monitoring site and the USGS streamflow gaging station Mancos River at Anitas Flat below Mancos, CO (USGS 09370600).
- *Mancos River above Downstream Park Boundary* (MEVEMAN02), identified in this report as MAN02, is a SCPN aquatic macroinvertebrate monitoring site. Once per year, NPS core water quality data are collected at this site.

In 2011, SCPN staff made a total of ten water quality sampling visits to MAN01 at regular intervals throughout the year. Limited water quality data were also collected at MAN02, concurrent with the aquatic macroinvertebrate sampling event on September 9. This report documents SCPN water quality monitoring activities at MEVE in 2011 and summarizes the data collected.

2 Methods

A brief description of water quality data collection and processing methodologies followed by SCPN staff at MEVE during 2011 is presented here. Detailed descriptions of these procedures will be available in SCPN's water quality monitoring protocol (Monroe et al. in preparation).

2.1 Water quality core parameters

National Park Service core water quality parameters include water temperature, pH, specific conductivity, dissolved oxygen, turbidity, and discharge. During each site visit, we noted the hydrologic conditions and collected water quality core parameter data using the following methods:

- Water and air temperatures were recorded at 15-minute intervals by a HOBO Pendant Temperature/Alarm Logger #UA-001-64, and a HOBO TidbiT v2 Water Temperature Data Logger, #UTBI-001 (Onset Computer Corporation) deployed at the monitoring site. The sensors were downloaded and maintenance was performed during each site visit. Sensor accuracy was confirmed using a NIST-certified thermometer during each download.
- As soon as possible after arrival at the site a multi-parameter sonde (Hydrolab-MS5; Hach Inc.) was calibrated and deployed in a well-mixed part of the stream channel, logging temperature, pH, specific conductivity, and dissolved oxygen data at 5-second intervals. The sonde was left stationary in the stream for the entire site visit.
- Turbidity samples were kept on ice for a maximum of 24 hours, and analyzed with a HACH 2100P Portable Turbidimeter (Hach Inc.).
- Discharge was measured using a FlowTracker Acoustic Doppler Velocimeter (SonTek Inc.).

We attempted to obtain all measurements and samples as close in time to one another as possible. Streamflow data from the USGS gaging station documented flow variation during site visits and throughout the year at 15-minute intervals.

In addition to the regular site visits, which were generally less than two hours long, we collected temperature, pH, specific conductivity, and dissolved oxygen data at 15-minute intervals from October 7–22 to characterize temporal variability of these parameters

2.2 Water quality samples

During each site visit, we collected a sample for bacterial analysis by dipping a sample bottle at the center of flow. The sample was then analyzed by SCPN staff for total coliforms and *E. coli* using the Quanti-Tray® 2000 system (IDEXX Inc.). We collected samples to be tested for other analytes in a similar manner. Sample water was filtered and/or acid-treated (as required), kept on ice, and shipped to the contract laboratory. For 2011, SCPN contracted with the USGS National Water Quality Laboratory (NWQL) in Denver, Colorado for analysis of water samples for selected water quality constituents. These analyses fall into three categories: nutrients, major elements and trace metals (Table 1). Information documenting NWQL methods are included in the SCPN water quality monitoring protocol (Monroe et al., in preparation).

Also in 2011, SCPN entered into a partnership with EPA to sample for a suite of contaminants of emerging concern (CEC), which include pharmaceuticals, personal care products, waste water indicators, and pesticides, to develop a baseline dataset documenting the occurrence of these contaminants within SCPN parks. Seven sampling events for these occurred at MAN01 between the months of May and October. Samples were kept on ice and analyzed at the EPA Region 8 Laboratory in Golden, Colorado within seven days of collection, as required.

2.3 Data handling and analysis

All SCPN water quality data are entered in NPSTORET, v.1.83, a Microsoft Access database created by the Water

Table 1. USGS National Water Quality Laboratory and U.S. Environmental Protection Agency Laboratory sample analytes.

Analytical group	Analytes
Nutrients	ammonia, nitrite, nitrite + nitrate, orthophosphate
Major elements	calcium, chloride, fluoride, magnesium, potassium, silica, sodium, sulfate, acid neutralizing capacity (ANC; as CaCO ₃), total dissolved solids
Trace metals	aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, silver, uranium, vanadium, zinc
Contaminants of emerging concern: pharmaceuticals, personal care products, waste water indicators, pesticides	see Appendix B of this report, Table B4

Resources Division of the National Park Service. All multiparameter sonde electronic data , discharge, and temperature logger files are stored on the SCPN server.

In this report, we only include the median values of a subset of seven consecutive multiparameter sonde measurements, with the exception of the data presented in section 3.3: *Temporal variability of core parameter data from the Mancos River in MEVE*. Similarly, only the median values for each set of turbidity triplicate samples are presented. For total coliforms and *E. coli* samples, most-probable numbers (MPN/100 mL) are reported; these were determined using a lookup table provided by the manufacturer (IDEXX Inc.).

Where applicable, we compared our results against the State of Colorado’s 2012 water quality standards (Colorado Department of Public Health and Environment [CDPHE] 2012a,b) and noted any exceedances of the applicable standards.

2.4 Understanding water quality data and standards

The NPS Natural Resource Challenge (NRC) provides funding for water quality monitoring in NPS park units. This funding supports efforts directed towards attainment of NPS’s long-term goals to protect pristine water quality and improve impaired water quality by supporting Clean Water Act protections and provisions for designated unimpaired and impaired waters. Preliminary analysis of data available through the water quality data synthesis (Brown 2008), a Level 1 water quality inventory (Macy and Monroe 2006), and monitoring indicate that water quality conditions at many SCPN parks exceed established USEPA, State or Tribal standards .

The State of Colorado has developed statewide water quality standards and criteria for surface waters, and specific additional criteria relevant to the reach of the Mancos River within MEVE, to meet requirements of the Federal Clean Water Act (CDPHE 2012a,b). This report includes all water quality standards and criteria applicable to the Mancos River. A water quality standard refers to a specific parameter and its associated beneficial-use designation, in conjunction with a criterion, which is the numeric component against which a result is compared. For example, the standard for chronic selenium (parameter) for aquatic life (beneficial use designation) is 4.6 µg/L (numeric criterion).

The SCPN water quality monitoring program collects samples several times per year at regular intervals in order to document the range of hydrologic conditions that occur, with a focus on base flow conditions. Thus, rare and short-term events are often not captured. Grab samples represent conditions at the point and time of sampling; they do not represent the condition of the entire water body, spatially or temporally.

In this report, results for each parameter are evaluated against applicable water quality standards as defined for each stream by the State of Colorado. Colorado surface waters can have up to five beneficial use classifications. Three appropriate beneficial uses are identified for the reach of the Mancos River and are discussed in this report. These are class 2 warm water aquatic life, agriculture, and recreation (class N from Nov. 1 to April 30, and class E from May 1 to Oct. 31) (CDPHE 2012b). Each beneficial use may have different criteria for one

parameter.

SCPN water samples are analyzed for dissolved parameters. This means stream water is passed through a 0.45 µm filter in order to remove the particulate component prior to being shipped for analysis. Water quality criteria may be expressed in terms of either the dissolved or total fraction of a sample. The total fraction concentration will be greater than the dissolved fraction. Because of this, only criteria for dissolved parameters are applicable to our samples, and only these criteria are listed in the Results sections.

For *E. coli*, we compared our results against the criteria for class N (not primary contact use) and class E (existing primary contact use) recreation, depending upon the time of year the samples were collected. The Colorado water quality criterion is expressed as the number of colony forming units per 100 mL (cfu/100 mL). SCPN bacteria data are expressed as a most probable number (MPN) per 100 mL. MPN is a statistical estimate of the number of bacteria per unit volume of a sample, determined by using a lookup table provided by the manufacturer (IDEXX Inc.). Although the Colorado criterion is expressed as cfu/100 mL and does not assume an estimation, the two units are comparable.

2.4.1 Chronic and acute standards

Numeric criteria for aquatic life water quality standards address potential effects of both chronic exposure to a parameter over an extended period of time (months) and acute exposure over a short period of time (hours or days). Acute criteria are based on either a single sample or an average of samples collected during a one-day period. Criteria are much lower for chronic exposure than for acute exposure and are not necessarily comparable to the results obtained from a one-time grab sample. This is because chronic standards are based on either a single representative sample or the average of all samples collected during a thirty-day period (CDPHE 2012a); the exact number of samples is not specified. When determining attainment of both acute and chronic standards, the representative nature of the data must be considered. From a compliance standpoint, the acute instantaneous criteria afford the only direct comparison for such data because they apply to a single sample. However, from a resource-conservation standpoint, instantaneous grab-sample data, when compared against more stringent chronic criteria, can provide a means of early warning and an indication of a problem that may require more attention. Therefore, we have identified when results are outside the chronic criterion in the Results section of this report.

2.4.2 Regulatory authority

The National Park Service does not have regulatory authority over waters in U.S., or even the authority to make assessments for designated use. This report compares water quality data to designated use criteria without stating whether a designated use was attained. Those designations are reported by the states or tribes in their triennial 305(b) reports to Congress. However, the NPS cooperates with states and tribes in collecting data used in the protection of water bodies under state jurisdiction. Definitions of water quality standards according to the states of Arizona, Colorado, New Mexico, Utah, and the Navajo Nation are provided in the SCPN Streams and Springs Water Quality Monitoring Protocol (Monroe et al. in review).

3 Results

3.1 Water quality core parameter data

Summary statistics for water quality core parameter data collected at MAN01 and MAN02 during 2011 are presented in Table 2 and Table 3; 2010 data for both sites are included for comparison. Complete results for MAN01 are displayed in Appendix B. Measurements at MAN02 were collected on September 9 and were similar to those collected at MAN01 on September 10. At MAN01, the data exhibited considerable within-year variability for several parameters (Table 2), but there were no exceedances of Colorado state water quality standards at MAN01 or MAN02 during our site visits (CDPHE 2012a.b).

Table 2. Summary of water quality core parameter data from samples collected at MAN01 on the Mancos River in Mesa Verde NP in 2010 (n=8) and 2011 (n=10, except for discharge, where n=9). Associated Colorado state aquatic life criterion is indicated for each parameter; “n/c” means that no criterion exists for a specific parameter.

Core parameter	2010		2011		CO state aquatic life criterion
	Median	Range	Median	Range	
Water temperature (°C)	8.5	0.4 – 25.2	7.2	0.0 – 23.4	^a
pH	8.3	7.9 – 8.6	8.3	7.9 – 8.4	>6.5 or <9
Specific conductivity (µS/cm)	1230	345 – 2210	1263	282 – 1350	n/c
Dissolved oxygen (mg/L)	9.3	7.2 – 11.4	9.5	6.8 – 11.4	>5
Turbidity (NTU)	12	7.2 – 120	25	7.9 – 150	n/c
Discharge (cfs)	18	4.6 - 269	20.3	6.3 – 213	n/c

^a See section 3.1 in text

Table 3. Water quality core parameter data collected from MAN02 on the Mancos River in Mesa Verde NP, concurrently with the collection of aquatic macroinvertebrate monitoring on one day in September 2010 and 2011 (n=1 for 2010 and 2011). The associated Colorado state aquatic life criterion is indicated for each parameter; “n/c” indicates that no criterion exists for a specific parameter.

Core parameter	2010	2011	CO state aquatic life criterion
Water temperature (°C)	13.4	14.4	^a
pH	8.3	8.4	>6.5 or <9
Specific conductivity (µS/cm)	1330	1283	n/c
Dissolved oxygen (mg/L)	8.6	8.5	>5
Turbidity (NTU)	18	9.0	n/c
Discharge (cfs)	10.4	10.8	n/c

^a See section 3.1 in text

Water and air temperature data from MAN01 for 2011 are summarized below and shown in Figure 2. The water in the Mancos River was frozen during portions of December, January, and February. The maximum water temperature for the year occurred on July 7 and was 29.2°C. The average water temperature was 9.0°C. The maximum air temperature was 36.9°C and occurred on July 2, while the minimum temperature of -31.0°C occurred on January 2. The average air temperature for the year was 7.7°C.

This section of the Mancos River is designated by the State of Colorado as a Class 2–Warm Water Biota stream (CDPHE 2012b). There are three “tiers” of temperature standards, depending on the assemblage of fish species expected to occur. The Tier III Warm Water stream standards are the least stringent (allowing the warmest water) and should be applied where thermally sensitive species are not expected to occur. Our data show that the

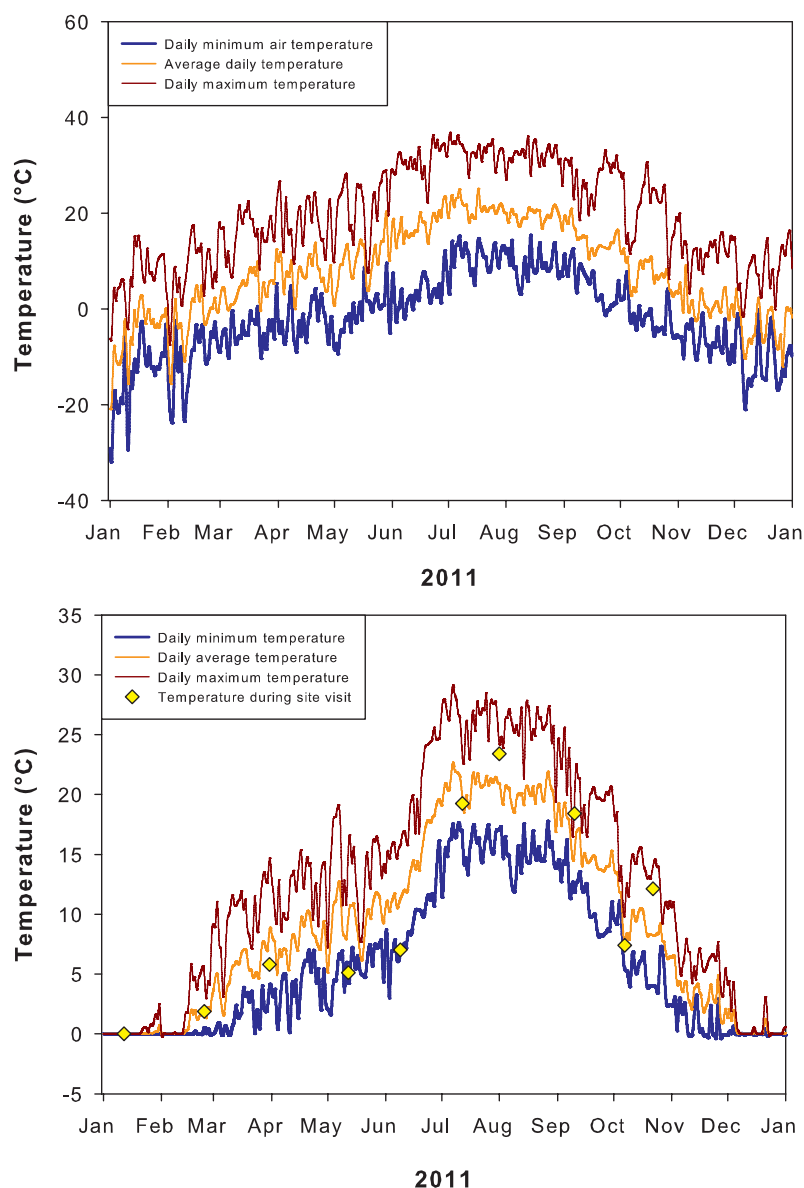


Figure 2. Daily maximum, average, and minimum air temperatures (top) and water temperatures (bottom) recorded at 15-minute intervals by a HOBO Pendant and HOBO TidbiT (Onset Computer Corporation) permanently deployed at MAN01 on the Mancos River in Mesa Verde NP, 2011. Water temperatures recorded during SCPN site visits using a multi-parameter sonde are also shown.

Mancos River temperatures were not outside these criteria in 2011. However, because of the historic presence of razorback sucker (*Xyrauchen texanus*) within this river reach (San Miguel, G., Natural Resource Manager, Mesa Verde NP, personal communication, 28 July 2011), we also evaluated the temperature against the Tier II Warm Water stream standards. The chronic water temperature criterion is a 27.5°C average over a seven-day period. River temperatures did not exceed this in 2011. The acute water temperature criterion is 28.6°C for more than two hours. This standard was exceeded only once, on July 7.

Measured pH at MAN01 was relatively consistent throughout the year, ranging from 7.9 to 8.4. All measurements were within the water quality criterion of >6.5 and <9.0 (CDPHE 2012b).

Specific conductivity at MAN01 ranged between 282 and 1350 $\mu\text{S}/\text{cm}$, with the highest values observed in the summer. Specific conductivity measurements were lower during the four sampling events from late March through June, when discharge was relatively high. Both pH and specific conductivity were more variable between the months of January and June than they were during the remainder of the year.

Dissolved oxygen ranged between 6.8 and 11.4 mg/L, well within the warm-water standard applicable to MAN01 (5 mg/L, CDPHE 2012b). Measurements were lowest in August, while the highest measured value occurred in January.

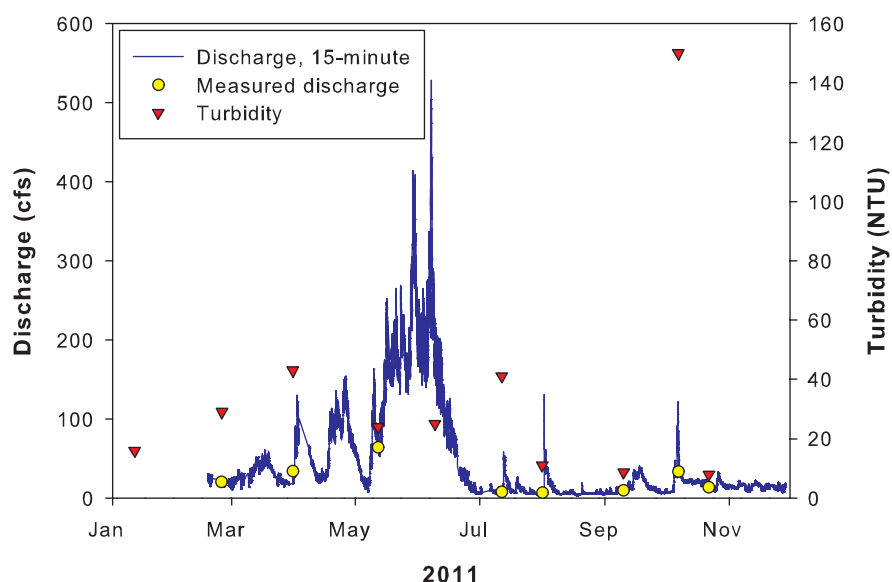


Figure 3. 15-minute streamflow data for the Mancos River from USGS gaging station Mancos River at Anitas Flat below Mancos, CO (09370600) in Mesa Verde NP shows measured discharge (in yellow) and turbidity (in red) for 2011.

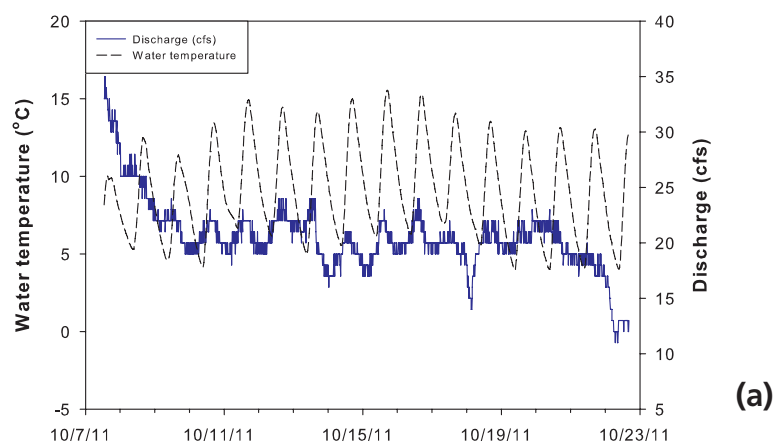
We measured the discharge of the Mancos River during each water quality sampling visit as part of an agreement with the USGS to collect and process data from the streamflow gaging station Mancos River at Anitas Flat below Mancos, CO (09370600) (USGS 2011). Two exceptions were January 12 when the river was frozen, and June 9 when the water level was too high to be measured safely. Measured flows ranged from 6.3 to 64.4 cfs. Figure 3 shows stream discharge plotted with turbidity for 2011. The hydrograph from the gaging station shows large peaks in flow during the May and June snowmelt period preceded by two smaller peaks in April. The highest discharge was 528 cfs on June 7. Turbidity was also higher during this snowmelt period than during the summer base flows. Turbidity levels ranged between 7.9 and 150 NTU; the highest measurement occurred on October 7 after precipitation occurred in the Mancos Valley.

3.2 Temporal variability of water quality core parameter data from the Mancos River in MEVE

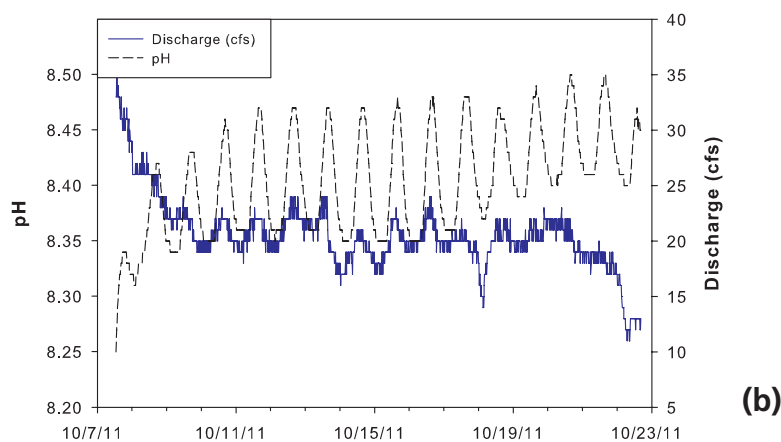
To assess temporal variability in core water quality parameters at MAN01, we deployed a multi-parameter sonde to record data at 30-minute intervals from October 7–22. These data are shown in Figure 4, along with the stream gage data. Significant precipitation, totaling 4.3 cm, occurred in the watershed three days prior to this deployment. Otherwise, the majority of the sampling period was dry with stable stream discharges, ranging from 11 to 35 cfs. Diel fluctuations in temperature averaged 9°C during this deployment. Fluctuations in pH averaged only 0.1 and most measurements were higher than those observed during our site visits in 2011. Dissolved oxygen averaged only 1.8 mg/L and changes in specific conductivity averaged 85 $\mu\text{S}/\text{cm}$. Table 4 summarizes the variability in water temperature, dissolved oxygen, pH, and specific conductivity during the 15-day deployment.

Table 4. Summary of water quality core parameter temporal variability at MAN01 on the Mancos River in Mesa Verde NP, October 7–22, 2011.

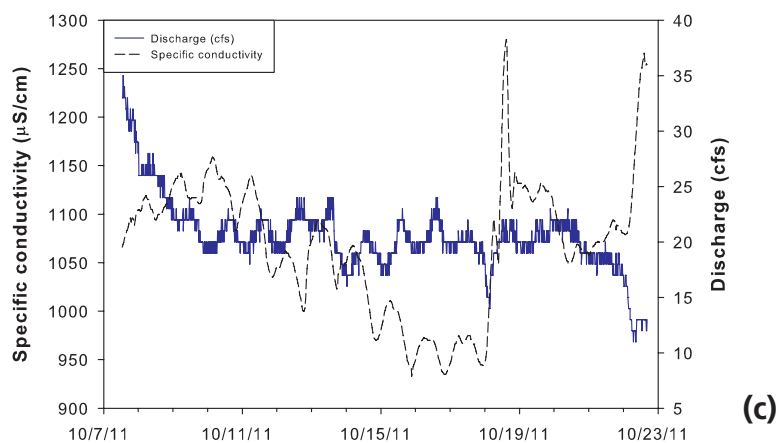
Core parameter	Minimum	Maximum	Median
Water temperature (°C)	3.9	15.5	8.8
Dissolved oxygen (mg/L)	7.9	10.5	9.2
pH	8.3	8.5	8.4
Specific conductivity ($\mu\text{S}/\text{cm}$)	933	1280	1080
Discharge (cfs)	11	35	20



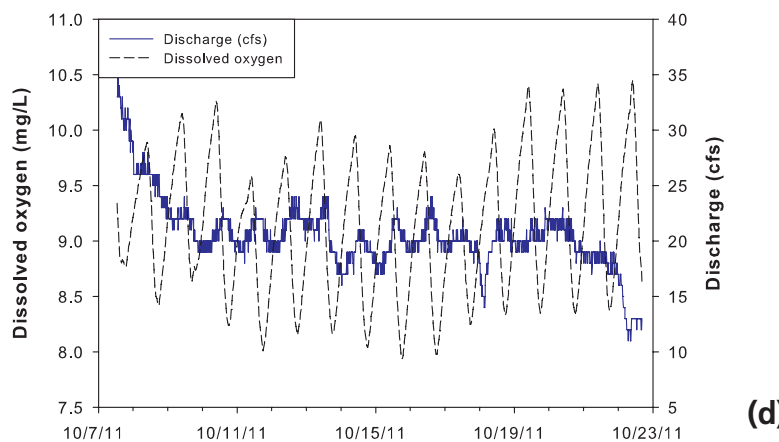
(a)



(b)



(c)



(d)

Figure 4. Multiparameter sonde data measured during a 15-day period from October 7-22, 2011 at MAN01 on the Mancos River in Mesa Verde NP: water temperature (a), pH (b), specific conductivity (c), and dissolved oxygen (d).

3.3 Total coliforms and *E. coli*

Bacteria data collected by SCPN at MAN01 in 2011 are shown in Figure 5 and presented in Appendix B; 2010 data are also included in the graph for comparison. SCPN's data are expressed as a most probable number (MPN) per 100 mL of stream water, a statistical estimate of the number of bacteria. Water quality criteria are expressed as colony forming units (cfu) per 100 mL and do not assume an estimation, but the two units are comparable. The Colorado state criteria values for *E. coli* are based on the geometric mean of at least four evenly-distributed samples collected over a 60-day period. The criteria applicable at MAN01 are 126 cfu/100 mL from May through October and 630 cfu/100 mL from November through April (CDPHE 2012b). We analyze our samples for total coliforms because theoretically they are indicators of the presence of all coliform groups of bacteria, both vegetative and fecal in origin. For drinking water, total coliforms are the standard diagnostic test because their presence indicates contamination of a water supply by an outside source. There are no water quality criteria for total coliforms.

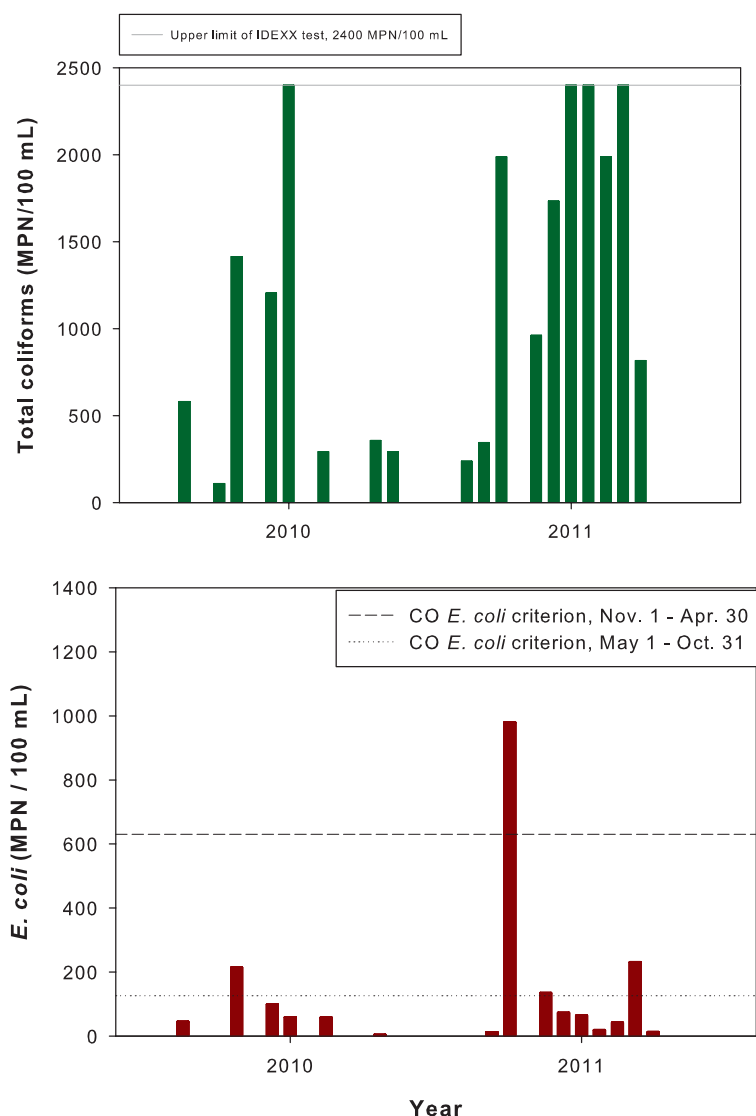


Figure 5. Total coliforms (top) and *E. coli* data (bottom) in samples collected from MAN01 on the Mancos River in Mesa Verde NP, 2010–2011.

E. coli levels were highest in a sample collected on March 31, at 980 MPN/100 mL. *E. coli* also exceeded the Colorado State criterion of 126 MPN/100 mL in May and October, though our sampling was not frequent enough to assess compliance with the water quality standard. The highest total coliform results were from samples collected in July, August, and October. These samples exceeded 2400 MPN/100 mL, the upper limit of the IDEXX test.

3.4 Water quality laboratory data

Seven water samples collected at MEVE by SCPN during 2011 were sent to NWQL to be analyzed for a suite of analytes (Table 1). These samples were collected at regular intervals throughout the year. Laboratory results for water samples are summarized in Tables 5–7; complete results are presented in Appendix B. Analysis of samples collected during 2011 did not exceed the State of Colorado water quality standards.

Nutrient concentrations (Table 5) were very low at all times of the year. Water quality standards exist for ammonia and nitrite, but measurements were well below these criteria. Four of the seven samples for ammonia, nitrite, and nitrite+nitrate were below their corresponding reporting levels. Orthophosphate was detected in six samples; levels remained relatively constant throughout the year, ranging between <0.00400 and 0.00874 mg/L.

Major element data, which includes major anions and cations, silica, acid neutralizing capacity, and total dissolved solids, are summarized in Table 6. Total dissolved solids, which mainly consist of the ions listed in Table 6 plus carbonate/bicarbonate, varied over the year from 356 mg/L to 1090 mg/L, with a median concentration of 1020 mg/L. Figure 6 depicts the major ion composition of the Mancos River during all water sampling events.

Anions mostly consisted of sulfate and, to a lesser extent, bicarbonate. Cation composition was more evenly mixed, with calcium comprising the highest proportion, followed by magnesium, then sodium. Potassium was the least prevalent cation. Major ion composition varied only slightly throughout the year, and 2011 results were very similar to those obtained in 2010.

Table 5. Summary of nutrient data from MAN01 (n=7) on the Mancos River in Mesa Verde NP, 2011, and number of times that the samples exceeded the applicable water quality criteria. A “n/c” indicates that no criteria exists for a particular nutrient. Results that were lower than the National Water Quality Laboratory reporting levels are noted as “<[reporting level]”. All nutrients are dissolved.

Nutrient	Minimum (mg/L)	Maximum (mg/L)	Median ^a (mg/L)	Standard deviation	Criterion (mg/L)	# of exceed-ances	Beneficial use
Ammonia as N	<0.0100	0.103	---	0.034	n/c	n/c	
Nitrite + nitrate as N	<0.020	0.144	---	0.056	n/c	n/c	
Nitrite as N	<0.00100	0.00495	---	0.0016	0.05	0	Aquatic life
Orthophosphate as P	<0.00400	0.00874	0.0072	0.0021	n/c	n/c	

^a The missing value symbol indicates that the median was not calculated when more than 70% of the results fell below the laboratory reporting level.

Table 6. Summary of major element data from samples collected at MAN01 (n=7) on the Mancos River in Mesa Verde NP, 2011. All major elements are dissolved, except for acid neutralizing capacity. There are no Colorado state water quality criteria for these analytes.

Major element	Minimum (mg/L)	Maximum (mg/L)	Median (mg/L)	Standard deviation
Calcium	58.2	172	157	44
Chloride	3.64	14.9	8.30	3.5
Fluoride	0.095	0.211	0.184	0.043
Magnesium	20.5	72.6	62.9	19.5
Potassium	1.60	3.76	2.94	0.83
Silica	6.91	12.2	9.43	1.8
Sodium	20.7	85.6	50.5	21.3
Sulfate	158	582	530	162
Acid neutralizing capacity, as CaCO ₃ , unfiltered	107	248	200	48
Total dissolved solids	356	1090	1020	291

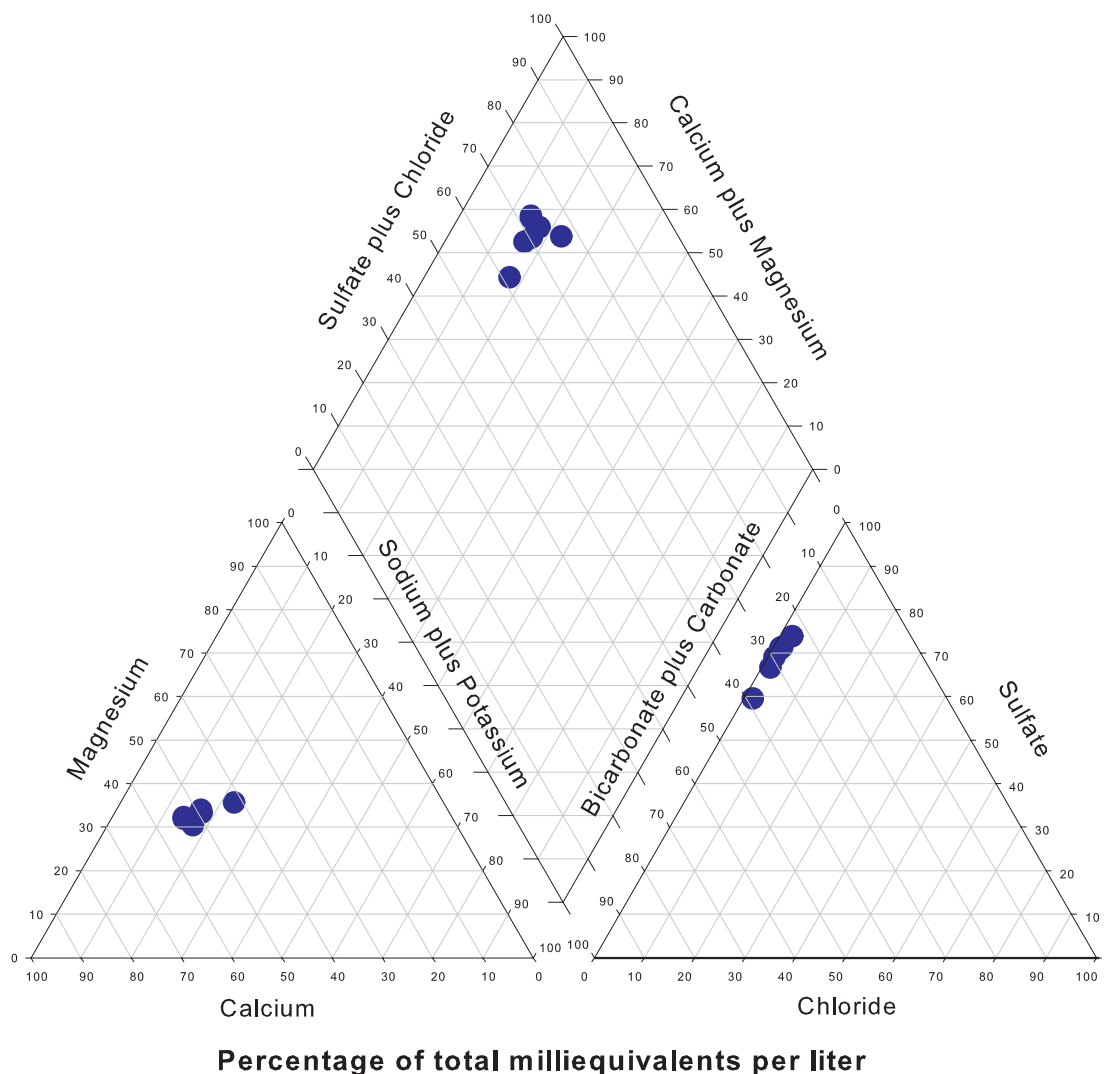


Figure 6. Major ion composition from samples collected at MAN01 on the Mancos River in Mesa Verde NP, 2011.

Table 7 reports the dissolved trace metals analyzed in 2011. All trace metals consistently measured below the water quality criteria, where applicable (CDPHE 2012b). This includes aluminum and selenium, which were outside the chronic aquatic life criterion once each in 2010. The water quality criteria are based on hardness and, because this varied between samples, the actual numeric criteria are expressed as a range where applicable. Mercury, silver, and zinc were not detected above the laboratory reporting level in 2011. Beryllium, cadmium, and chromium were only detected once each, all in July.

3.5 Contaminants of emerging concern

SCPN collected eight water samples at MAN01 from May through October to be analyzed by the EPA Region 8 Laboratory for a suite of 206 contaminants of emerging concern. The complete dataset is in Appendix B, and detections for 18 contaminants, all in ng/L concentrations, are summarized in Table 8. Of these, only nonylphenol, pentachlorophenol, naphthalene, and fluoranthene have water quality standards assigned to them. Our results are well below these criteria, as the criteria are listed in $\mu\text{g/L}$ (nonylphenol and pentachlorophenol) and mg/L (naphthalene and fluoranthene).

Table 7. Summary of trace metal data from samples collected at MAN01 (n=7) on the Mancos River in Mesa Verde NP, 2011, and number of times that the samples were outside the applicable water quality criterion. A “n/c” indicates that no dissolved criterion exists for a particular trace metal. Results that were lower than the NWQL reporting levels are noted as “<[reporting level]”

Trace metal, dissolved	Minimum (µg/L)	Maximum (µg/L)	Median ^a (µg/L)	Standard deviation ^a	Criterion (µg/L)	# of exceed-ances	Beneficial use
Aluminum	<1.70	72.1	2.89	28.7	n/c	n/c	
Antimony	0.0961	0.134	0.109	0.013	n/c	n/c	
Arsenic	0.290	1.03	0.348	0.27	150 (chronic)	0	aquatic life
Barium	41.4	56.9	47.2	5.6	n/c	n/c	
Beryllium	<0.0060	0.0078	---	---	n/c	n/c	
Boron	17.9	72.4	41.8	21.7	750, 30 day	0	agriculture
Cadmium	<0.016	0.022	---	---	0.80–1.20 (chronic)	0	aquatic life
Chromium	<0.060	0.075	---	---	141 (Cr(III), 11 Cr(IV) (chronic)	0	aquatic life
Cobalt ^b	0.385	0.787	0.577	0.137	n/c	n/c	
Copper	1.19	5.46	1.49	1.58	18.3–29.3	0	aquatic life
Iron ^b	6.7	156	10.0	54	n/c	n/c	
Lead	<0.0150	0.155	0.0272	0.050	6.18–10.9 (chronic)	0	aquatic life
Manganese ^b	17.3	78.6	44.8	23.6	2180–2618 (chronic)	0	aquatic life
Mercury	<0.005	<0.005	---	---	n/c	n/c	
Molybdenum ^b	0.882	2.69	2.16	0.71	n/c	n/c	
Nickel	0.947	2.35	1.80	0.5	106–168 (chronic)	0	aquatic life
Selenium	0.59	2.57	1.17	0.67	4.6 (chronic)	0	aquatic life
Silver	<0.0050	<0.0050	---	---	1.35–3.47 (chronic)	0	aquatic life
Uranium	1.11	5.15	3.96	1.43	3776–6915 (chronic)	0	aquatic life
Vanadium	0.112	0.614	0.216	0.169	n/c	n/c	
Zinc	<1.40	<1.40	---	---	259–428	0	aquatic life

^a Values not reported were not calculated because more than 70% of results were below the laboratory reporting level.

^b Results of a field blank indicated contamination with small concentrations of cobalt (0.0464 µg/L), iron (4.37 µg/L), manganese (0.154 µg/L), and molybdenum (0.0338 µg/L). Therefore, we have flagged all results for these trace metals except for those that fell below the NWQL reporting levels.

Table 8. Summary of detections of contaminants of emerging concern in samples collected at MAN01 (n=8) on the Mancos River in Mesa Verde NP, 2011.

Contaminant	Use	# of detections
Pharmaceuticals and personal care products		
Metformin	Type-2 diabetes drug used to control blood glucose	5
Gabapentin	anticonvulsant, painkiller	7
Gemfibrozil	cholesterol medication	1
Waste indicators		
Bisphenol A	used in the production of polycarbonate plastics and epoxy resins (hard plastic bottles and metal food cans)	3
Tri(dichloroisopropyl) phosphate	flame retardant in foams, resins, and latexes	2
17 beta-estradiol	estrogenic hormone, used in pharmaceuticals	2
Camphor	odorant, flavorant, plasticizer, cosmetics, preservative	3
Nonylphenol	breakdown product from detergents	3
Tri (2-butoxyethyl) phosphate	flame retardant, plasticizer in rubber and plastics, used in floor polishes	2
<i>p</i> -cresol	solvent, disinfectant, and chemical intermediate	2
Triclosan	antimicrobial ingredient	1
Naphthalene	produced during coal and oil combustion, used in the manufacture of PVC plastics, used in mothballs	1
Pentachlorophenol	formerly a widely-used pesticide, wood preservative	2
Methyl salicylate	fragrance	1
Carbazole	produced during coal combustion, used to make dyes	1
Pesticides		
Propachlor OA	herbicide	1

4 Quality assurance/Quality control

We followed the Quality Assurance/Quality Control procedures described in Monroe et al. (in preparation) and in National Park Service 2012. Prior to each sampling event, the multiparameter sondes were calibrated, maintained, and compared to one another indoors. The streamflow current meter was checked to be in proper working order according to manufacturer recommendations, and the turbidimeter was checked for calibration drift in the lab prior to each sampling event and in the field prior to each measurement. Fifteen duplicate bacteria samples were collected at several SCPN monitoring sites by filling two sample bottles in succession and comparing tray results after the incubation period. Thirteen blank samples were processed using sterile water provided by IDEXX. To verify the cleanliness of both the sampling equipment and the sample filtration process for nutrients, major elements, and trace metals, NWQL analyzed one sample set of certified inorganic blank water at the end of 2011.

In December 2011, SCPN sent one set of samples with certified inorganic blank water to NWQL for nutrients, trace metals, and major elements. Most analytes were not detected, but four trace metals were detected at low concentrations: cobalt (0.0464 µg/L), iron (4.37 µg/L), manganese (0.154 µg/L), and molybdenum (0.0338 µg/L); indicating possible contamination during the processing of the field samples. At MEVE, most detections were significantly lower than the field samples reported in tables 5–7 and appendix B; however, blank results were within 10% of the following stream sample results for iron: 8.8, 8.9, 6.7, 31.1, 10, and 20.1 µg/L; and cobalt: 0.385 and 0.453 µg/L.

5 Summary

In 2010, SCPN implemented long-term water-quality monitoring at MAN01 on the Mancos River in MEVE. Data collected during ten site visits to MAN01 in 2011 is summarized here and compared against applicable Colorado water quality standards (CDPHE 2012a,b).

We made site visits at regular intervals throughout the year, capturing a variety of different seasonal and flow conditions. Discharge at the time of sample events ranged from 6.3 to 213 cfs. Turbidity ranged from 7.9–150 NTU. Specific conductivity ranged from 345–2210 µS/cm. Dissolved oxygen measurements ranged from 6.8–11.4 mg/L. Measured pH was between 7.9 and 8.4. Water temperatures were logged at 15-minute intervals year-round and did not exceed the chronic water temperature criterion, but exceeded the acute criterion of 28.6°C for one day in July, 2011. A long-term sonde deployment at MAN01 during a hydrologically stable 15-day period showed regular diurnal patterns in water temperature, dissolved oxygen, pH and specific conductivity.

Results of SCPN's analyses for total coliforms in 2011 ranged from 240 MPN/100 mL in January to >2400 MPN/100mL, the upper limit for the analysis method used, in July, August, and October. Results of analyses for *E. coli* ranged from <1 MPN/100 mL in January to 980 MPN/100 mL in March. The sample collected in March, as well as results for samples collected in May and October, all exceeded the State of Colorado's water quality criteria for *E. coli*. SCPN's sampling strategy is not designed to assess compliance with water quality standards and further sample collection would be required to make a definite determination.

Laboratory-measured results for nutrients and trace metals were below applicable water quality criteria. Mercury, silver, and zinc were not detected in any of the seven samples. Major ion analyses show that the water at MAN01 is dominated by sulfate and calcium. Total dissolved solids were generally high, except during spring snowmelt, and ranged from 356 to 1090 mg/L, with a median of 1020 mg/L. Acid neutralizing capacity was also lower during the spring snowmelt period; CaCO₃ values ranged from 107 to 248 mg/L with a median of 200 mg/L.

The data in this report should be viewed as a snapshot of water quality conditions existing at the time that the data was collected. Data and analyses in this report are provisional and are subject to change. When sufficient data are available, SCPN plans to produce an interpretive report which will include trend analysis of water quality data for the Mancos River in Mesa Verde National Park.

6 Literature cited

- Brown, J. B. 2008. Review of available water-quality data for the Southern Colorado Plateau Network and characterization of water quality in five selected park units in Arizona, Colorado, New Mexico, and Utah, 1925 to 2004: U.S. Geological Survey Scientific Investigations Report 2008–5130.
- Colorado Department of Public Health and Environment. 2012a. The basic standards and methodologies for surface water (5 CCR 1002-31). Regulation No. 31. Water Quality Control Commission, Denver, Colorado.
- Colorado Department of Public Health and Environment. 2012b. Stream classifications and water quality standards. Regulation No. 34.6(4). Water Quality Control Commission, Denver, Colorado.
- Colorado Water Trust. 2011. Mancos River basin instream flow report – Preliminary evaluation of flow restoration options. Report prepared for The Mancos Conservation District. Denver, Colorado.
- Macy, J. P., and S. A. Monroe. 2006. Water-quality data for selected National Park units in the Southern Colorado Plateau Network, Arizona, Utah, Colorado, and New Mexico, water years 2005 and 2006: U.S. Geological Survey Open-File Report 2006–1300.
- Monroe, S. A., C. A. Bliss, and M. Dyer. (In preparation). Water quality monitoring protocol for the Southern Colorado Plateau Network. National Park Service, Fort Collins, Colorado.
- National Park Service, Water Resources Division and Inventory and Monitoring Program. 2012. Quality Assurance Project Plan for surface water sampling for pesticides, pharmaceuticals, personal care products, waste water indicators in the National Park Service’s Northern Colorado Plateau, Southern Colorado Plateau, Sierra Nevada, Sonoran Desert and Southern Plains Inventory and Monitoring Networks. Unpublished report, Fort Collins, Colorado.
- Scott, M. L., A. M. D. Brasher, A. M. Caires, E. W. Reynolds, and M. E. Miller. 2005. The structure and functioning of riparian and aquatic ecosystems of the Colorado Plateau: Conceptual models to inform monitoring. Report to the Southern and Northern Colorado Plateau Networks. Supplement III *in* Thomas, L. P., M. N. Hendrie, editor, C. L. Lauver, S. A. Monroe, N. J. Tancreto, S. L. Garman, and M. E. Miller. 2006. Vital signs monitoring plan for the Southern Colorado Plateau Network: Natural Resources Report NPS/SCPN/NRR-2006/002, National Park Service, Fort Collins, Colorado. Available at http://science.nature.nps.gov/im/units/scpn/assets/docs/Supplements/SuppIII_Riparian_Aquatic_Model.pdf (accessed 8 August 2011).
- Stacey P. 2007. Functional assessment of the Mancos River watershed: Mancos Valley and adjacent areas. Mancos Conservation District, Mancos, Colorado. Available at <http://biology.unm.edu/stacey/Functional%20Assessment%20of%20the%20Mancos%20River%20Watershed.pdf>.
- Thomas, L. P., M. N. Hendrie, editor, C. L. Lauver, S. A. Monroe, N. J. Tancreto, S. L. Garman, and M. E. Miller. 2006. Vital signs monitoring plan for the Southern Colorado Plateau Network: Natural Resources Report NPS/SCPN/NRR-2006/002, National Park Service, Fort Collins, Colorado. Available at <http://science.nature.nps.gov/im/units/scpn/publications.cfm> (accessed 8 August 2011).
- United States Environmental Protection Agency (EPA). 2011. Impaired waters and total maximum daily loads. Available at <http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl> (accessed 22 November 2011).
- United States Geological Survey (USGS). 2011. National Water Information System: Web Interface. USGS, Denver, Colorado. Available at <http://waterdata.usgs.gov/nwis/uv?09370600>.
- Western Regional Climate Center, Desert Research Institute. 2012. Period of record monthly climate summary page for remote automatic weather station (RAWS) MRFC2. WRCC/DRI Reno, NV. Available at <http://www.raws.dri.edu/cgi-bin/rawMAIN.pl?coCMRF>. (Accessed January 2013).
- Yochum, Steven E. 2004. Mancos Valley Salinity: Hydrologic Study Report. Natural Resources Conservation Service, Northern Plains Engineering Team. Lakewood, Colorado.

Appendices

Appendix A: Southern Colorado Plateau Network water quality monitoring sites

Table A1. Southern Colorado Plateau water quality monitoring sites for Mesa Verde National Park, 2011.

Site code	Common name	Report name	Northing (m) ¹	Easting (m) ¹	Elevation (m) ¹
MEVEMAN01	Mancos River at Gage	MAN01	4126163	734375	1933
MEVEMAN02	Mancos River above downstream boundary	MAN02	4122566	735878	1882

¹ Horizontal coordinates are reported in Universal Transverse Mercator (UTM) Projection, Zone 12, North American Datum of 1983 (NAD 83). Vertical coordinates are referenced to the North American Vertical Datum of 1988 (NAVD 88).

Appendix B: Water quality monitoring results for the Mancos River at Mesa Verde National Park, 2011

Table B1. Water quality core parameter data from MAN01 on the Mancos River in Mesa Verde NP, 2011.

Parameter	Unit	Sample collection date and time									
		1/12 11:37	2/24 12:51	3/31 10:52	5/12 9:30	6/9 9:00	7/12 11:00	8/1 15:10	9/10 17:00	10/7 12:50	10/22 18:15
Water temperature	°C	0.0	2.2	6.5	5.3	7.0	19.3	23.4	18.4	7.4	12.1
pH	none	7.9	8.3	8.3	8.1	8.0	8.4	8.2	8.3	8.3	8.3
Specific conductivity	μS/cm	1280	1300	777	497	282	1350	1350	1320	1060	1250
Dissolved oxygen	mg/L	11.4	10.7	10.0	9.5	9.6	7.7	6.8	7.6	9.5	8.1
Turbidity	NTU	16	29	43	24	25	41	11	8.6	150	7.9
Discharge	cfs	ice	20.3	33.8	64.4	213	7.6	6.3	9.7	33.4	13.3

Table B2. Total coliforms and *E. coli* in samples collected at MAN01 on the Mancos River in Mesa Verde NP, 2011.

Parameter	Unit	Sample collection date and time									
		1/12 11:37	2/24 12:51	3/31 10:52	5/12 9:30	6/9 9:00	7/12 11:00	8/1 15:10	9/10 17:00	10/7 12:50	10/22 18:15
Total coliforms	MPN/100 mL	240	340	2000	960	1700	>2400 ^a	>2400 ^a	2000	>2400 ^a	820
<i>E. coli</i>	MPN/100 mL	<1	12	980	140	73	64	19	43	230	13

^a Exceeded the maximum detection level of IDEXX system, which is 2400.

Table B3. Results of laboratory analyses for samples collected from MAN01 on the Mancos River in Mesa Verde NP in 2011. Samples were analyzed by the U.S. Geological Survey National Water Quality Laboratory (NWQL). Results that were lower than the NWQL reporting levels are noted as "<[reporting level]". All analytes were dissolved, except acid neutralizing capacity.

Analyte	Sample collection date and time						
	1/12	2/24	3/31	5/12	7/12	9/10	10/22
	11:37	12:51	10:52	9:30	11:00	17:00	18:15
Nutrients (mg/L)							
Ammonia as N	0.103	0.0347 ^a	<0.0100	0.0158	<0.0100	<0.0100	<0.0100
Nitrite + nitrate as N	0.144	0.131 ^a	<0.020	0.050	<0.020	<0.020	<0.040
Nitrite as N	0.00495	0.00312 ^a	<0.00100	0.00311	<0.00100	<0.00100	<0.00100
Orthophosphate as P	0.00721	0.00874 ^a	0.00430	0.00849	0.00856	0.00487	<0.00400
Major elements (mg/L)							
Calcium	157	140	92.2	58.2	161	172	170
Chloride	10.3	14.9	5.97	3.64	8.30	8.67	8.18
Fluoride	0.175	0.184	0.142	0.095	0.202	0.211	0.211
Magnesium	64.3	72.6	33.9	20.5	67.6	62.9	61.3
Potassium	2.66	2.94	1.93	1.60	3.76	3.61	3.35
Silica	9.43	8.02	6.91	8.64	10.9	12.2	10.4
Sodium	61.5	85.6	30.9	20.7	61.2	50.4	50.5
Sulfate	545	582	287	158	556	530	494
Acid neutralizing capacity, as CaCO ₃ (unfiltered)	214	194	142	107	248	211	200
Total dissolved solids	1030	1090	562	356	1080	1020	961
Trace metals (µg/L)							
Aluminum	<1.70	2.02	12.2	49.8	72.1	2.16	2.89
Antimony	0.0985	0.108	0.119	0.109	0.134	0.116	0.0961
Arsenic	0.290	0.342	0.344	0.348	1.03	0.696	0.518
Barium	49.9	46.0	42.8	41.4	56.9	47.2	53.7
Beryllium	<0.0060	<0.0060	<0.0060	<0.0060	0.0078	<0.0060	<0.0060
Boron	41.8	41.8	24.3	17.9	71.9	72.4	59.0
Cadmium	<0.016	<0.016	<0.016	<0.016	0.022	<0.016	<0.016
Cobalt ^b	0.486	0.577	0.787	0.629	0.385	0.453	0.655
Copper	1.49	1.37	3.42	5.46	2.29	1.32	1.19
Chromium	<0.060	<0.060	<0.060	<0.060	0.075	<0.060	<0.070
Iron ^b	8.8	8.9	6.7	31.1	156	10.0	20.1
Lead	0.0261	<0.0150	0.0272	0.0516	0.155	0.0345	<0.0250
Manganese ^b	78.6	67.4	44.8	17.3	25.9	24.5	57.6
Mercury	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Molybdenum ^b	1.67	2.16	1.13	0.882	2.57	2.69	2.32
Nickel	1.67	1.80	1.31	0.947	2.14	1.98	2.35
Selenium	1.51	2.57	0.656	0.590	1.17	1.65	1.17
Silver	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Uranium	4.20	5.15	1.80	1.11	3.66	4.03	3.96
Vanadium	0.112	0.186	0.177	0.216	0.614	0.364	0.256
Zinc	<1.40	<1.40	<1.40	<1.40	<1.40	<1.40	<1.40

^a Nutrient samples arrived warm (7°C) to the NWQL, nutrients should be kept <4°C.

^b Results of a field blank indicated contamination with small concentrations of cobalt (0.0464 µg/L), iron (4.37 µg/L), manganese (0.154 µg/L), and molybdenum (0.0338 µg/L).

Table B4. Contaminant of emerging concern detections in samples collected at MAN01 on the Mancos River in MEVE, 2011. All results are in ng/L. Analytes listed in this table were detected at least once during the 2011 monitoring season. In those instances where the analyte was not detected above the reporting level, the table cell is left blank. Only a few of the analytes had Colorado state aquatic life criteria, and none exceeded these criteria. A duplicate sample was taken on July 12, 2011 for quality control.

Analyte	Reporting limit	Sample collection date and time							
		5/12	6/9	7/12	7/12	8/1	9/10	10/7	10/22
		9:30	9:00	11:00	11:00	15:10	17:00	12:50	18:15
Pharmaceuticals and personal care products									
Metformin	10.0	101 ^{a,b}	13.9			27.4		22.2	38.5
Gabapentin	25.0	233 ^{a,b}	116 ^b	50.7 ^b	54.0 ^b		137 ^b	501 ^d	447 ^b
Gemfibrozil	10.0							11.2	
Waste indicators									
Bisphenol A	50.0		115 ^c	180				79.6	
Tri(dichloroisopropyl) phosphate	50.0		66.4 ^c		51.8				
17beta-estradiol	50.0		87.0 ^c	123 ^c					
Camphor	50.0			57.2	85.5			53.8	
Nonylphenol ^e	50.0			97.7	168			90.4	
Tri(2-butoxyethyl) phosphate	50.0			292			224		
<i>p</i> -cresol	50.0				57.8				79.2
Triclosan	50.0				72.5				
Naphthalene ^f	50.0							53.4	
Pentachlorophenol ^g	50.0							83.4	424
Methyl salicylate	50.0							91.2	
Carbazole	50.0								58.8
Pesticides									
Propachlor OA	10.0		16.5						

^a Samples were analyzed outside of holding time - all results are estimated values

^b Laboratory calibration acceptance criteria not met - all results are estimated values

^c Laboratory QA/QC acceptance criteria not met - all results are estimated values

^d Laboratory matrix spike acceptance criteria not met, result is estimated

^e Colorado state aquatic life criteria for Nonylphenol are: acute=28,000 ng/L, chronic=6,600 ng/L

^f Colorado state aquatic life criteria for Naphthalene are: acute=2,300,000 ng/L, chronic=620,000 ng/L

^g Colorado state aquatic life criteria for Pentachlorophenol are: acute=19,000 ng/L, chronic=15,000 ng/L

Appendix C. List of analytes and reporting limits for contaminants of emerging concern

Table C1. Target analytes and U.S. Environmental Protection Agency reporting limits for pesticides.

Analyte	Reporting limit (ng/L)	Analyte	Reporting limit (ng/L)
2,4,5-T	10	EPTC	20
2,4,5-TP	10	Ethoprop	10
2,4-D	10	Fipronil	20
3-Hydroxycarbofuran	10	Fipronil sulfide	10
Acetochlor	20	Hexazinone	10
Acetochlor OA	20	Imazaquin	20
Alachlor	20	Imazethapyr	10
Alachlor OA	50	Imidacloprid	20
Aldicarb	10	Linuron	20
Aldicarb sulfone	20	Malathion	10
Aldicarb sulfoxide	10	MCPP	20
Atrazine	10	Metaxyl	10
Atrazine de-ethyl	20	Methiocarb	10
Atrazine de-isopropyl	20	Methomyl	20
Atraton	50	Metolachlor	10
Azoxystrobin	20	Metolachlor ESA	20
Bentazon	10	Metribuzin	20
Bromacil	50	Monuron	10
Bromoxynil	10	Neburon	50
Butachlor ESA	10	Oryzalin	20
Carbaryl	10	Oxamyl	10
Carbofuran	10	Pentachlorophenol	50
Chlorimuron ethyl	20	Prometon	10
Cyanazine	10	Propachlor	10
3-Hydroxycarbofuran	10	Propachlor ESA	20
Dacthal monoacid	20	Propazine	50
Diazinon	10	Propiconazole	20
Dichloroprop	10	Propoxur	10
Dimethachlor	10	Simazine	20
Dimethenamid	10	Sulfometuron methyl	20
Dimethenamid ESA	20	Tebuconazole	50
Disulfoton sulfone	20	Tebuthiuron	10
Diuron	50	Terbutylazine	10
Diuron Metabolite	50	Thiamethoxam	20

Table C2. Target analytes and reporting limits for pharmaceuticals and personal care products

Analyte	Reporting limit (ng/L)	Analyte	Reporting limit (ng/L)
Acebutolol	10.0	Fenbufen	10.0
Albuterol	10.0	Fentanyl	10.0
Alprazolam	10.0	Flunitrazepam	10.0
Amitriptyline	10.0	Furosemide	10.0
Amitriptyline, (+/-)-E-10-hydroxylated	10.0	Gabapentin	25.0
Amphetamine	10.0	Gemfibrozil	10.0
Atenolol	10.0	Glipizide	10.0
Atrazine	10.0	Glyburide	10.0
Benzoyllecgonine	10.0	Hydrocodone	10.0
Benzphetamine	10.0	Hydromorphone	10.0
Bezafibrate	10.0	m-Hydroxybenzoyllecgonine	10.0
Brombuterol	10.0	Ibuprofen	10.0
Butabarbital	25.0	Levorphanol	10.0
Butalbital	10.0	Loratadine	10.0
n-Butylparaben	25.0	Mefenamic acid 3-carboxy	10.0
Carbamazepine 10,11 epoxide	10.0	MDA	10.0
Caffeine	10.0	MDEA	10.0
Cannabidiol	25.0	MDMA	10.0
Cannabinol	25.0	Meperidine	10.0
Carbamazepine	10.0	Mephobarbital	25.0
Carisoprodol	10.0	Meprobamate	10.0
Chloramphenicol	10.0	Metformin	10.0
Chlordiazepoxide	10.0	Methamphetamine	10.0
Chlorpheniramine	10.0	Methaqualone	10.0
Cimetidine	10.0	Methylparaben	10.0
Clenbuterol	10.0	Methypyrrolon	10.0
Clobazam	10.0	Metoprolol	10.0
Clonazepam	10.0	Monensin	10.0
Clonidine	10.0	Morphine	10.0
Cocaethylene	10.0	Naproxen	10.0
Cocaine	10.0	Nifedipine	10.0
Codeine	10.0	Nifedipine oxidized	10.0
DEET	10.0	Nitrazepam	10.0
Dextromethorphan	10.0	Norfentanyl	10.0
Diazepam	10.0	Norfluoxetine	10.0
Diclofenac	10.0	Norverapamil	10.0
Diltiazem	10.0	Omeprazole	10.0
Diphenhydramine	10.0	Oxycodone	10.0
Ecognine Methyl Ester	10.0	Oxymorphone	10.0
Erythromycin	10.0	Paroxetine	10.0
Famotidine	10.0	Pentazocine	10.0
Fenbendazole	10.0	Phencyclidine	10.0

Table C2. Target analytes and U.S. Environmental Protection Agency reporting limits for pharmaceuticals and personal care products, *continued*

Analyte	Reporting limit (ng/L)	Analyte	Reporting limit (ng/L)
Phenmetrazine	10.0	Temazepam	10.0
Phenobarbital	10.0	Testosterone	10.0
Phentermine	10.0	(+/-)11-nor-9-carboxy-delta-THC	10.0
Phenylpropanolamine	10.0	THC	25.0
Phenytoin	10.0	Thebaine	10.0
Pindolol	10.0	Thiabendazole	10.0
Prazepam	10.0	Tramadol	10.0
Progesterone	10.0	Trazodone	10.0
Propranolol	10.0	Triamterene	10.0
Pseudoephedrine	10.0	Triazolam	10.0
Ranitidine	10.0	Triclocarban	10.0
Secobarbital	10.0	Triclosan	10.0
Sildenafil	10.0	Trimethoprim	10.0
Simvastatin	10.0	Tylosin	10.0
Sotalol	10.0	Venlafaxine	10.0
Sulfamethazine	10.0	Verapamil	10.0
Sulfamethoxazole	10.0	Warfarin	10.0
Talbutal	25.0		

Table C3. Target analytes and U.S. Environmental Protection Agency reporting limits for wastewater indicators.

Analyte	Reporting limit (ng/L)	Analyte	Reporting limit (ng/L)
Acetophenone	50.0	17beta-Estradiol	50.0
Benzophenone	50.0	Estrone	50.0
Bisphenol A	50.0	Ethinylestradiol	50.0
Bromacil	50.0	Fluoranthene	50.0
Butylated Hydroxyanisole	50.0	Galaxolide	50.0
Caffeine	50.0	Indole	50.0
Camphor	50.0	Isoborneol	50.0
Carbaryl	50.0	Isophorone	50.0
Carbazole	50.0	Isoquinoline	50.0
Celestolide	50.0	Menthol	50.0
Chlorpyrifos	50.0	3-Methyl Indole	50.0
p-Cresol	50.0	Methyl Salicylate	50.0
4-Cumylphenol	50.0	2-Methylnaphthalene	50.0
Dacthal	50.0	1-Methylnaphthalene	50.0
Diazinon	50.0	2,6-Dimethylnaphthalene	50.0
1,4-Dichlorobenzene	50.0	Metolachlor	50.0
Dichlorvos	50.0	Musk ketone	50.0
Equilenin	50.0	Naphthalene	50.0

Table C3. Target analytes and U.S. Environmental Protection Agency reporting limits for wastewater indicators *continued*

Analyte	Reporting limit (ng/L)	Analyte	Reporting limit (ng/L)
Nonylphenol	50.0	Tonalide	50.0
4-n-Octylphenol	50.0	Tributyl Phosphate	50.0
4-tert-Octylphenol	50.0	Triclosan	50.0
Pentachlorophenol	50.0	Tri(dichloroisopropyl) Phosphate	50.0
Phantolide	50.0	Triethyl Citrate	50.0
Phenanthrene	50.0	Tri(2-butoxyethyl) Phosphate	50.0
Phenol	50.0	Tri(2-chloroethyl) Phosphate	50.0
Prometon	50.0	Triphenyl phosphate	50.0
Pyrene	50.0		

Appendix D. Abbreviations, chemical formulas, and symbols used in this report

Term	Definition
CaCO ₃	chemical formula for calcium carbonate
cfs	cubic feet per second
cfu/100 mL	colony forming units, for bacteria sampling, a measure of the number of viable bacteria per 100 mL
µg/L	micrograms per liter, equivalent to one part per billion
µS/cm	microsiemens per centimeter at 25°C, a measure of specific conductivity
mg/L	milligrams per liter, equivalent to one part per million
Milliequivalents per liter	an expression of the concentration of substances that is chemically equivalent in terms atomic weight and electrical charge
MPN/100 mL	most probable number, for sampling bacteria, a statistical estimation of the number of coliforms that would give the results shown by the laboratory examination
N	chemical symbol for the element nitrogen
ng/L	nanograms per liter, equivalent to one part per trillion
NTU	nephelometric turbidity unit, a measure of turbidity
P	chemical symbol for the element phosphorous