

Water Quality Monitoring for Missouri National Recreational River, Bow Creek

2021 Data Report

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Photograph of Bow Creek Wynot, NE at Missouri National Recreational River, June 2021 looking upstream from the bridge.

A wide brownish-green river has steep grassy banks with cropland at the top. Deciduous trees fill the background.

Photograph by USGS, station 06478522.



View downstream from gage near Wynot, NE, Bow Creek, June 2021.

Wide river with ripples and sand bars visible. Trees are on banks.

Photograph by USGS, station 06478522.

Abstract

The Northern Great Plains Inventory and Monitoring Network (NGPN) began monitoring water quality in Bow Creek at Missouri National Recreational River in 2015, with the assistance of the U.S. Geological Survey (USGS). This report summarizes the data collected during the 2021 ice-free season (March 24 through December 15) for water temperature, dissolved oxygen, specific conductance, and pH. Streamflow is measured year-round. This was the third season of continuous monitoring.

2021 ended up being a very dry year with less than 50% of the yearly average precipitation after an even drier year in 2020. Daily mean discharge peaked at 425 cubic feet per second (and maximum instantaneous discharge of 556 cfs) on February 24, 2021, considerably lower than the record peak in 2019 of 12,500 cfs, which translated to below average streamflow. Water quality also was measured including in 2015 which had a peak of 2,220 cfs, and 2018 which had a peak of 7,440 cfs. There was considerable seasonal variation in all water quality measures. A summary of our results can be found

in the Descriptive Statistics Summary tables for the ice-free season (Table 2) and for each month (Table 3). Water temperature exceeded state standards 3.82% of the time.

Nebraska Department of Environment and Energy monitors *Escherichia coli* (*E. coli*) bacteria in Bow Creek. *E. coli* can be a human health concern. Between 2016 and 2021, bacteria levels exceeded standards for moderately used recreational waters (298 cfu/100 mL) 83 % of the time in reach (MT2-11300) and the geomean standard (126 cfu/100 mL) exceeded standards in 2016 and 2020. Bow Creek remains nonsupporting of its recreation use due to *E. coli*. There is no approved TMDL for *E. coli*, placing it in category 5, but Lewis and Clark NRD does have a watershed plan to improve the water quality in Bow Creek.

NGPN's collaboration with USGS supported real-time and archived access to this data through the USGS National Water Information System Website [Bow Creek near Wynot, Nebr. - USGS Water Data for the Nation](#) where it remains available to the public.

List of Terms or Acronyms

>:	greater than
≥:	greater than or equal to
<:	less than
≤:	less than or equal to
#:	number
303(d) list:	List of Impaired Waters, under the CWA
cfs:	cubic feet per second
CWA:	Clean Water Act
°C:	degrees Celsius
DO:	dissolved oxygen
<i>E. coli</i> :	<i>Escherichia coli</i>
EPA:	Environmental Protection Agency
I&M:	Inventory & Monitoring
IRMA:	Integrated Resource Management Applications
km ² :	square kilometers
mi ² :	square miles

mL:	milliliters
MNRR:	Missouri National Recreational River
NAWQA:	National Water Quality Assessment (USGS)
NE:	Nebraska
NDEE:	Nebraska Department of Department of Environment and Energy
NGPN:	Northern Great Plains Network
NPS:	National Park Service
NWIS:	National Water Information System (U.S. Geological Survey)
SC:	Specific conductance
SOP:	standard operating procedure
TNC:	The Nature Conservancy
WRSA:	Wild and Scenic Rivers Act
USEPA:	U.S. Environmental Protection Agency
USGS:	U.S. Geological Survey

Introduction

Bow Creek is a small creek in an agricultural watershed in northeast Nebraska. Over 70% of the watershed is in cultivated crops, with grassland covering the remainder. Bow Creek’s headwaters are in Knox County, west of Highway 81 and it flows northeast 47 miles to meet the Missouri at Bow Creek Recreation Area in Cedar County. The unit is part of the 59-mile district area now managed as part of MNRR (NPS 2017) in partnership with other agencies including the US Army Corps of Engineers, US Fish and Wildlife, Nebraska Game and Parks Commission, and the South Dakota Department of Game, Fish, and Parks. NPS land within MNRR consists of 887 acres within a 48,456-acre area (NPS 2024). MNRR consists of two districts. The 39-mile district consists of the Missouri River upstream of Lewis and Clark Lake and runs from Fort Randall Dam, including the confluence with the Niobrara River to Running Water, SD. The 39-mile district includes 8 miles of lower Verdigris Creek and the lower 20 miles of Niobrara River. This district is dam-influenced. The 59-mile district begins just downstream of Gavins Point Dam to Ponca, NE. This district consists of a wide, meandering channel in free-flowing condition. Sandbar, forested floodplain, and floodplain wetland habitats are prevalent throughout the district (NPS 2017).

MNRR has five significant park features. The first feature is the unique geology. In MNRR, two contrasting geologic landscapes are visible: the Cretaceous bluffs and the glacial landscapes of the

Pleistocene. MNRR protects some of the last dynamic channel habitats in the Missouri River basin such as sandbars, islands, side channels, and riparian cottonwood forest. The park has a rich history of human use from prehistoric times to Fort Randall. The recreational opportunities are special, with river access points and land and water trails. The scenic views of the river valley and features are considered significant. Similarly, the fundamental resources and values and outstanding remarkable values (ORVs) have been identified: cultural values, ecological values, fish and wildlife values, free-flowing condition and water quality values, geological values, recreational values, and scenic views. These values as the special characteristics a river possesses that warrant special protection under the WSRA. Each segment in MNRR can include some or all of the defined ORVs.

Cultural values of MNRR include significance to local tribes, archeological sites, the Mormon monument, the Ponca Fort, and Fort Randall Historic Site. Ecological values include a dynamic channel and floodplain system, one that is rare due to dam infrastructure and impacts. Fish and wildlife values include 704 species of plants and 424 fish and wildlife species (NPS 2012). Ninety-three species of fish and 154 species of birds (NPS 2017) dwell in MNRR. Federally listed least terns and piping plovers call MNRR's sandbars home. The park is an important refuge for reptiles and amphibians. Invasive species such as purple loosestrife and zebra mussels threaten terrestrial and aquatic habitats. Dam activity threatens wildlife habitat.

MNRR has hot, humid summers and winters ranging from mild to very cold (Stark 2011). Cedar County Nebraska's 1991-2020 mean July temperature is 73.8° F. The mean January temperature is 20.3° F, and the county receives on average 29.01 inches of precipitation (1991-2020, NCEI 2024). Year-to-year precipitation can be highly variable (Stark 2011). In 2021, Cedar County received 18.99 inches of precipitation, well below the 30-year average, but following high precipitation years in 2019 and 2020. Average temperature for the year in 2021 was 49.8°F, well above the 30-year mean of 48°F and 100-year mean of 47.5°F (1921-2020), making 2021 a drier and warmer year on average.

Bow Creek has primary contact recreation, aquatic life, agricultural, and aesthetic beneficial uses. The Niobrara River within MNRR is designated as a Nebraska warmwater Class A stream for aquatic life. Warmwater class waters are those which provide, or could provide, a habitat consisting of sufficient water volume or flow, water quality, and other characteristics such as substrate composition which can maintain year-round populations of warmwater biota. Class A waters are those that provide, or could provide, a habitat suitable for maintaining one or more identified key species on a year-round basis. These waters also can maintain year-round populations of a variety of other warmwater fish and associated vertebrate and invertebrate organisms and plants. These differ from class B warmwater criteria where warmwater biota is limited by flow, water quality, substrate composition, or other habitat conditions (NDEE 2019). Warmwater biota are life forms in waters where temperatures frequently exceed 25°C (77°F). Figure 1 shows the water quality impairments in the Bow Creek vicinity.

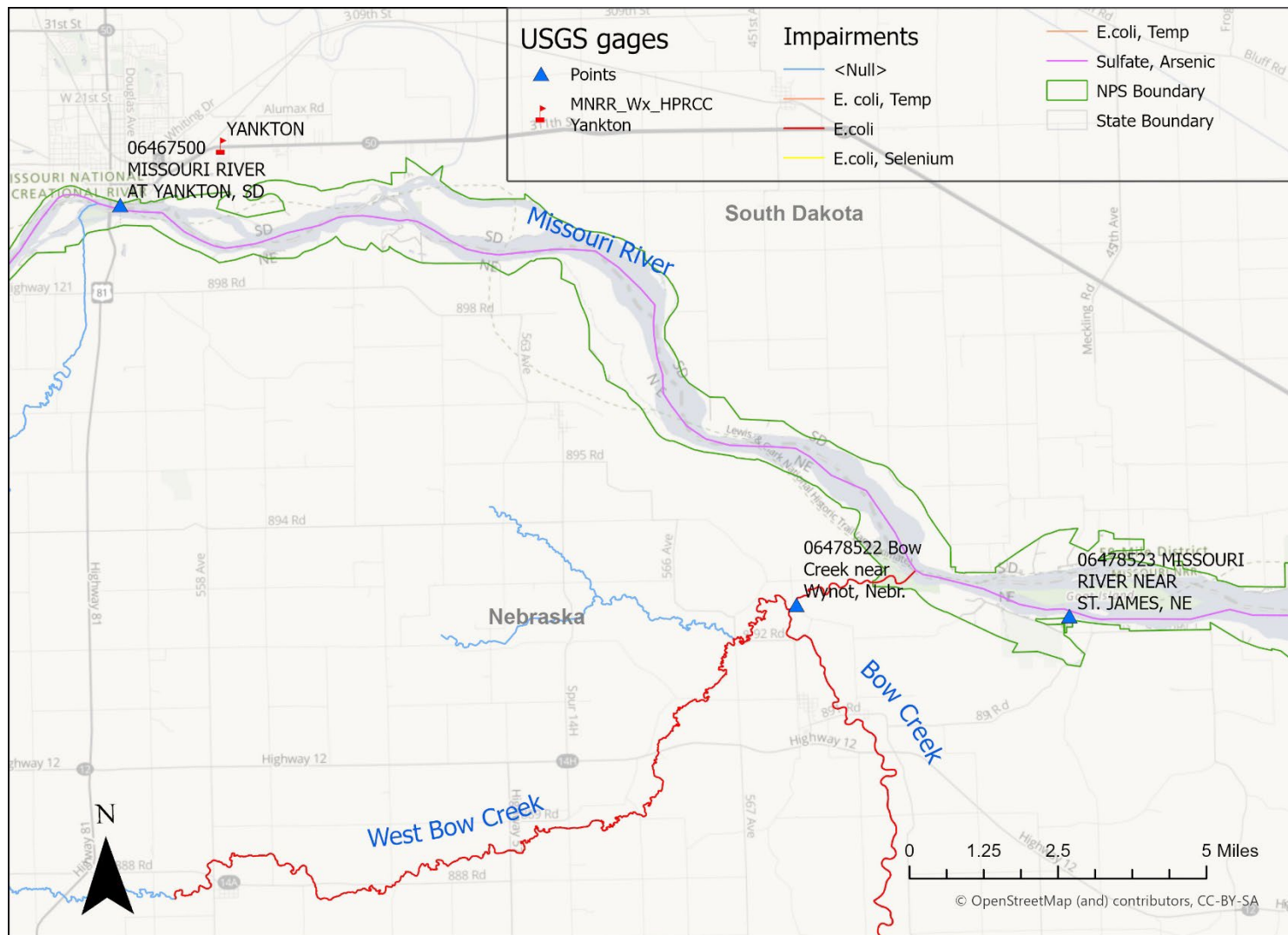


Figure 1. Map of Missouri National Recreation River, eastern portion. The water quality impairments for streams in the vicinity are color-coded. Blue indicates the river is meeting state standards. Both the upper and lower portions of Bow Creek are impaired for *E. coli*, but there is a watershed plan. The water quality monitoring station on Bow Creek, 06478522, and the weather station at Yankton are also indicated.

Figure #1. Map of Missouri National Recreation River, including Bow Creek.

“Figure 1. Map of streams in MNRR vicinity including Bow Creek. Impaired reaches are labeled by color including Bow Creek which is impaired for *E. coli* bacteria.”

While the Northern Great Plains Inventory & Monitoring Network (NGPN) does not collect *E. coli* data, it is important to summarize some of the data available, as *E. coli* is a pollutant of concern. *E. coli* bacteria impairments are present in Bow Creek in MNRR. Primary contact waters should not exceed a geometric mean of 126 cfu/ 100 mL or 298 cfu/100 mL for moderately used recreational waters. There are not a lot of geomean data because sampling has usually been performed monthly. A geomean requires that five samples be taken within a 30-day calendar period.

Four monthly geomeans were collected by NDEE at lower Bow Creek MT2-11300 at 3 miles north of Wynot each in 2016 and 2021, four of which violated standards in 2016 and two of which violated standards in 2021. Given that only one geomean violation would result in an impairment, this reach is clearly impaired. Seventy-nine out of 95 samples at that location since 2016 exceeded the single sample maximum of 298 cfu/100 mL. Data are publicly available from water quality portal, [Water Quality Data Home](#). There is not an approved TMDL in place to address the pollution but Lewis and Clark Natural Resource District (NRD) has a watershed plan to improve sediment, phosphorus, nitrogen, and *E. coli*. Summaries for Bow Creek at MNRR are available at [How's My Waterway - Waterbody Report \(epa.gov\)](#).

NGPN began monitoring water quality at Bow Creek at MNRR in 2015 to better understand current conditions and changes over time in Bow Creek. The monitoring has been conducted at the gaging station at near Wynot, NE (Monitoring Location 06478522; Figure 2) in collaboration with the USGS. The objective is to determine the status and long-term trends of core water quality parameters during the ice-free season. NGPN plans to repeat water quality monitoring at Bow Creek every three years, and an in-depth analysis of status and trends will be conducted after three to five cycles of sampling (Wilson, et al. 2014).

NGPN's core water quality parameters include streamflow, dissolved oxygen (DO), pH, specific conductivity, and water temperature (Table 1; Wilson, et al. 2014). These parameters are measured every 15 minutes throughout the ice-free season (typically March to November), and results were made available in real-time on the USGS National Water Information System website.

Table 1. Water quality parameters measured as part of the Northern Great Plains Inventory & Monitoring Water Quality Program and associated state standards for Nebraska warmwater class A waters (NDEE 2019).

Table #1: Water quality parameters measured as part of the Northern Great Plains Inventory & Monitoring Water Quality Program and associated state standards for Nebraska warmwater class A waters (NDEE 2019).

Water Quality Parameter	Description	NE state standards applicable to warm water fisheries designations
Water temperature (°C)	Water temperature is affected by solar radiation, air temperature, rainfall, flow dynamics, stream shading, in-stream bed material, reflectance, and land use/cover in the watershed.	- For warm waters, the maximum limit is 32°C. - The maximum increase shall not be greater than five degrees Fahrenheit (3°C) above natural background conditions.
Dissolved Oxygen (mg/L)	Dissolved oxygen level is a measure of the amount of oxygen in the water column and an important indicator of a water body's ability to support aquatic life.	- One day minimum of not less than 5 mg/L for early life stages. Applies April 1 through September 30. - One day minimum of not less than 3 mg/L for all life stages other than early life stages. Applies October 1 through March 31. - Seven-day mean minimum of not less than 4.0 mg/L. Applies October 1 through March 31. - Seven-day mean of not less than 6.0 mg/L for early-life stages. Applies April 1 through September 30. - Thirty-day mean of not less than 5.5 mg/L. Applies October 1 through March 31.
Specific Conductance (µS/cm)	Specific conductivity is a measure of the water's ability to conduct electricity. Specific conductivity is typically proportional to the dissolved major ions in the water such as calcium, magnesium, sodium, and sulfate.	Agricultural use dictates conductivity cannot exceed 2000 umhos/cm (µS/cm) between April 1 and September 30.
pH	The pH of the stream is a measure of the hydrogen ion concentration in the water. Different organisms flourish within different ranges of pH.	PH is to be maintained between 6.5 – 9.0, unless due to natural conditions.

Methods

The NGPN Water Quality Monitoring Protocol (Wilson, et al. 2014) sets out the methods used for sampling water quality and streamflow. The general approach is briefly described below. For more detail, please see Wilson, et al. 2014 (available at <https://www.nps.gov/im/ngpn/water-quality.htm>).

Data Collection

Water quality data are collected at a real-time USGS stream gage (ID number 06478522) just outside the park near Wynot, NE at approximately 1,165 ft elevation. Water quality is measured every fifteen minutes throughout the ice-free season. Water quality monitoring at MNRR was conducted in 2015, 2018, and 2021; and will continue to be repeated every three years. Program funding currently limits monitoring to a cycle of one year of monitoring, followed by two years without monitoring. Streamflow is monitored every 15 minutes, continuously every year, and has been monitored since 2015.

In 2021, NGPN continued to partner with the USGS Nebraska Water Science Center to have USGS staff collect water quality and streamflow data at MNRR. The USGS deployed a continuous, multi-parameter sonde off the bridge, station 06478522 on March 24, 2021 (Figure 2) and visited the gaging station (Figure 3) every three to four weeks for equipment maintenance (Table 2). This instrument recorded dissolved oxygen, pH, specific conductivity, and water temperature every fifteen minutes, while the gage simultaneously measured stream stage (or gage height) and discharge, a measure of streamflow.



Figure 2. A sonde device is used to measure water quality on Bow Creek in 2021 at Missouri National Recreational River. This sonde is coated with fine sediment.

Figure #2. Water quality sonde used to monitor Bow Creek at MNRR during 2021 with sediment coating the sonde inside and outside.

“Figure 2. Water quality sonde with coating of sediment.”



Figure 3. The radar head for the gage is attached to the bridge at station 06478522, Bow Creek.

Figure #3. The radar head for the gage is attached to the bridge at station 06478522, Bow Creek.

“Figure 3. The radar head for the gage is attached to the bridge at station 06478522, Bow Creek.

Table 2. Field journal for 2021 Water Quality Sampling at Bow Creek, Missouri National Recreational River.

Table #2: Field journal for 2021 Water Quality Sampling at Bow Creek, Missouri National Recreational River.

Date	Notes
24-Mar-21	Installed water quality (WQ) monitor off bridge, hanging position.
4-Apr-21	SC stopped working after visit.
23-Apr-21	Moved EXO sonde from bridge to right bank under the bridge.
13-May-21	Acid-soaked probes except pH.
3-Jun-21	Swapped SC, PH, and DO probe. Heavy scaling. Cross-section completed.
24-Jun-21	Acid soaked probes.
13-Jul-21	Cleaned EXO meter. Wiper issues.
5-Aug-21	Stream too shallow for cross-section. Acid-soaked probes.
24-Aug-21	Channel dry under wire weight. Swapped out all probes.
16-Sep-21	Soaked sonde to cleans scaling. Cross-section performed.
7-Oct-21	Acid-soaked probes. Cross-section.
28-Oct-21	Acid soaked probes. Cross-section.
15-Dec-21	Removed probe for season. Cross-section completed. Acid-soaked probes. Wiper issues.

The field journal in Table 2 recounts 13 visits made to the site during the 2021 monitoring season.. See further details in the station analysis in Appendix A. 96% of the temperature measurements were published and the record was rated ‘excellent’. 82% of the specific conductance measurements were published and that record was rated ‘fair’. 94% of pH measurements are published and the record is rated ‘excellent’. 91% of dissolved oxygen records were published and were rated ‘excellent’.

Satellite telemetry transmitted the water data to the Water Science Center in near real-time ([Bow Creek near Wynot, Nebr. - USGS Water Data for the Nation](#)). The USGS staff reviewed the real-time data daily to verify the accurate transfer of provisional field data and to identify sensor malfunctions or erroneous data. Access to the real-time data allowed them to recognize problems due to recording equipment malfunction, sedimentation, electrical disruption, debris, or vandalism. If disruptions occurred, the USGS staff scheduled additional site visits to minimize the loss of data.

During each site visit, USGS staff conducted a site inspection and a side-by-side comparison with the in-the-water sonde and an independent field sonde. They serviced and calibrated the sensors as needed, if possible. Calibration included pre- and post-calibration checks to quantify fouling errors and equipment drift, which are data critical to the correction and grading of the final data.

Quality assurance and quality control were conducted by USGS staff following established USGS guidelines (Wagner, et al. 2006). NGPN received the final corrected (approved) data in January 2022 from the USGS, and used AQUARIUS Workstation by Aquatic Informatics

(<http://aquaticinformatics.com/>) and R (R Core Team 2023) to store and analyze the water data.

Water year reports are provided by USGS, and the text can be found in Appendix A. Figures were generated in R, and daily mean values were calculated from fifteen-minute interval data. In the case where data values were missing due to instrument error, the means were generated by excluding the missing values; the daily maximum and minimum were left blank for these days. Means were not calculated on days where all time steps were missing (i.e., the instrument did not collect any data that day). The proportion of records that exceeded Nebraska environmental regulatory thresholds were calculated and are shown in Table 1.

Climate data were downloaded from the RAWS Yankton Climate Station (#399502). The data were accessed and graphed using the web-based tool [Climate Analyzer](#).

Results

The water quality monitoring season (ice-free) on the Niobrara River lasted from March 24, 2021 to December 15, 2021. The discharge in Bow Creek peaked in late February with a lower peak occurring in July. 2021 was a drier than average year. Discharge peaked at 536 cfs on February 24th and slowly decreased throughout the growing season (Figure 4). Mean annual discharge was 89.3 cfs and the minimum discharge occurred on August 15, 2021 with a recorded value of 15.1 cfs.

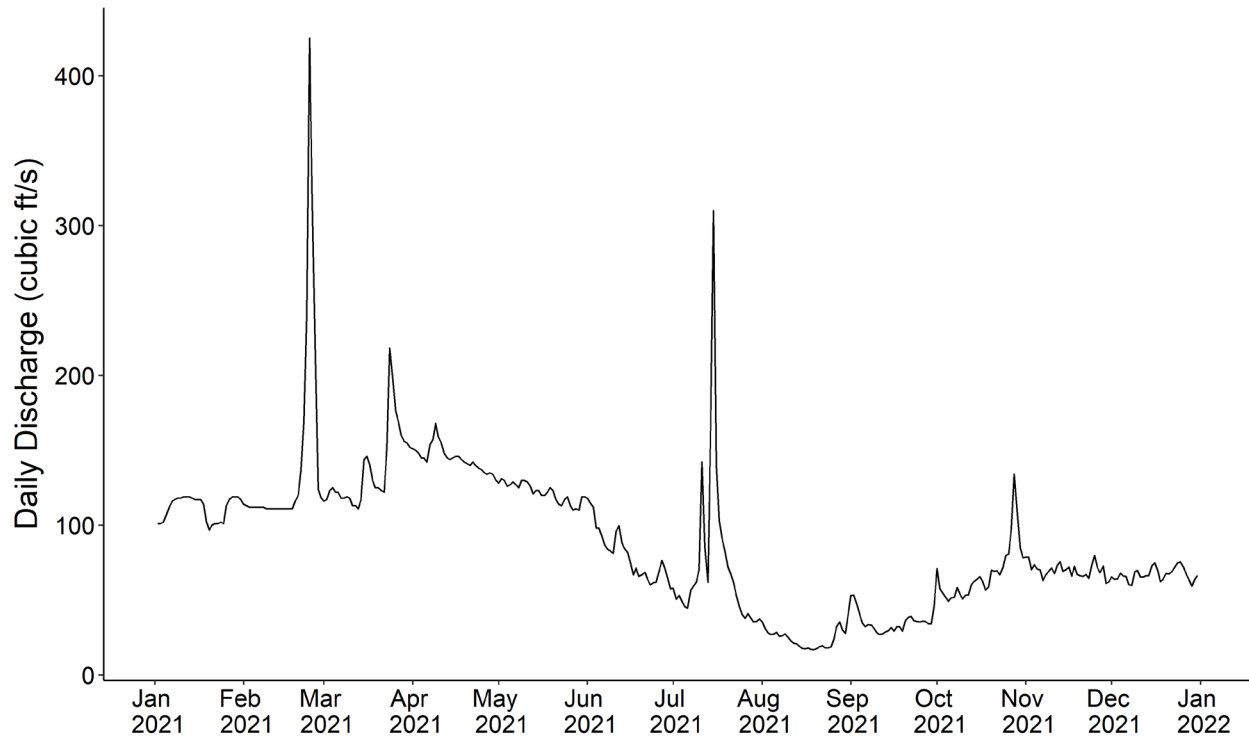


Figure 4. Daily mean discharge (black line) in 2021 on Bow Creek at Missouri National Recreational River, USGS Gaging station 06478522.

Figure #4. Daily mean discharge (black line) in 2021 on Bow Creek at Missouri National Recreational River, USGS Gaging station 06478522.

“Figure 4. Daily mean discharge (black line) in 2021 on Bow Creek at Missouri National Recreational River, USGS Gaging station 06478522.”

Figures 5 and 6 show some of the 2021 weather data from the Yankton weather station available here: [Yankton \(climateanalyzer.us\)](https://climateanalyzer.us). Figure 5 focuses on monthly precipitation, minimum and maximum temperatures. Figure 6 depicts departures from the 1990-2020 averages. Overall 2021 was a warmer-than average year except for February which was very cold. It was also a drier than average year, receiving only about 50% of average precipitation.

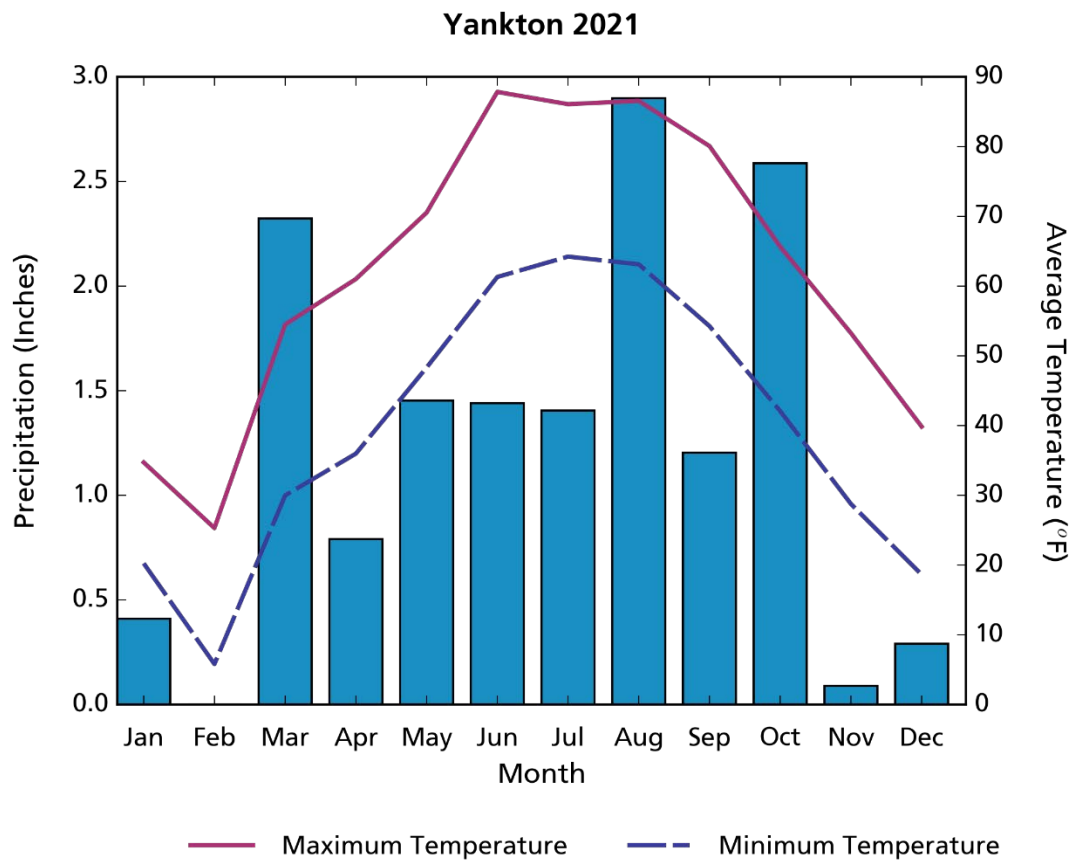


Figure 5. The above graph shows the total monthly precipitation (blue bars), average monthly minimum temperature (dashed blue line) and average monthly maximum temperature (solid red line) for the 2021 calendar year at Missouri National Recreational River. Climate data are from Yankton RAWS climate station (climateanalyzer.us). The data were accessed and graphed using the web-based tool Climate Analyzer.

Figure 5. Total monthly precipitation, average monthly minimum temperature, and average monthly maximum temperature for the 2021 calendar year at Missouri National Recreational River.

“Figure 5. Bar graph showing total monthly precipitation. Line graphs show average monthly minimum temperature, and average monthly maximum temperature for the 2021 calendar year at Missouri National Recreational River. “

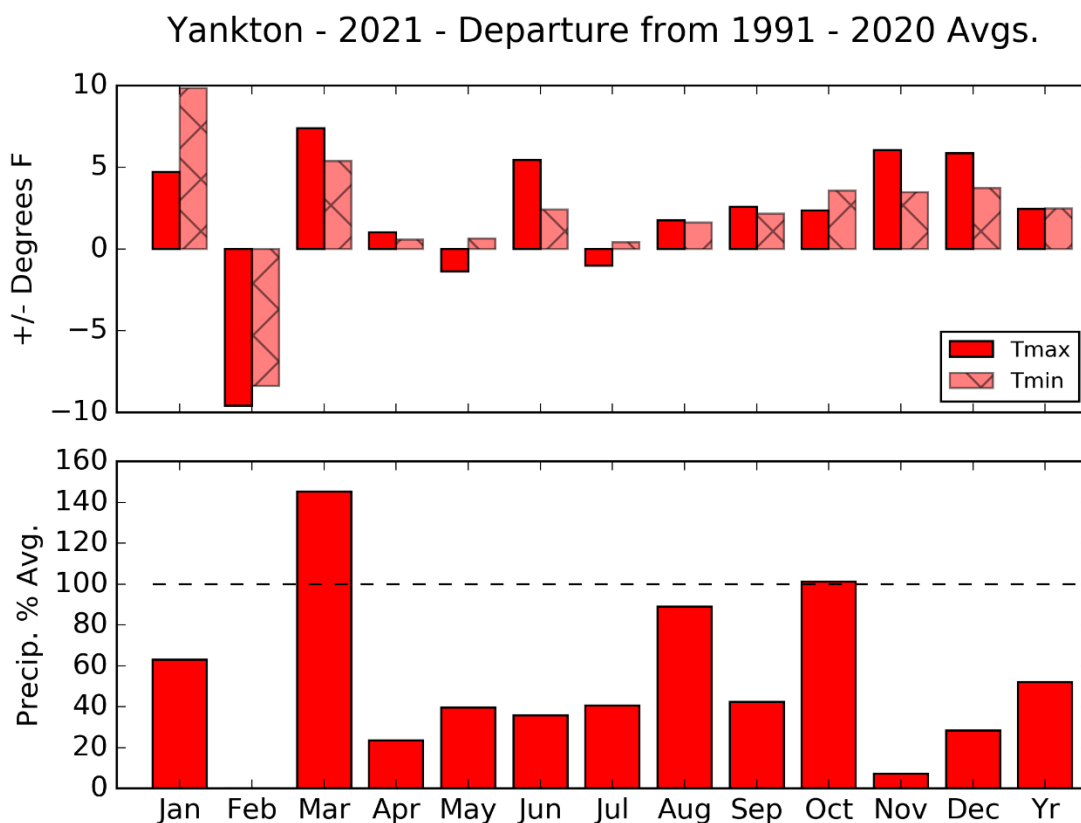


Figure 6. A comparison of 2021 temperature (top) and precipitation (bottom) at Missouri National Recreational River compared to 1991-2020 averages. Climate data are from Yankton RAWS climate station. The data were accessed and graphed using the web-based tool [Yankton \(climateanalyzer.us\)](https://climateanalyzer.us/).

Figure #6. Total monthly precipitation, average monthly minimum temperature, and average monthly maximum temperature departures for the 2021 calendar year as compared to 1991-2020 averages at Missouri National Recreational River.

“**Figure 6.** Bar graph showing the departure from normal of Tmin (minimum temperature) and Tmax (maximum temperature) for each month in 2021. February was far below average while January and March were much above average. Overall the year was above average for temperature. Bottom graph shows the total monthly precipitation. March had above average rainfall, while the summer months and November were much below average. Overall the year showed about half the average rainfall.”

During the ice-free season at MNRR, over 20,000 water quality measurements in the Niobrara River were collected, although some sensors on the multi-parameter sonde experienced errors and data were not recorded (Table 3). This monitoring period had a mean water temperature of 17.93°C, a mean dissolved oxygen concentration of 9.33 mg/L, a mean specific conductance of 325 µS/cm, and a mean pH of 8.55 (Table 3). There was, however, variation across months in all parameters (Table 4). Mean water temperature in April was 11°C and increased to a mean of 26.95 °C in July before declining down to 12.71°C in October (Table 4, Figure 7). Dissolved oxygen fell below the Nebraska

water quality standard of 5 mg/L .23% of the time with 48 observations in the summer months (Table 4). PH exceeded state standards 2.85% of the time, with exceedances falling between July and October.

Table 3. Summary of descriptive statistics for water temperature, dissolved oxygen, specific conductance, and pH measured for the ice-free sampling period at Missouri National Recreational River in the Niobrara River from March 24 to December 15, 2021. Percent exceedance is the proportion of samples that exceed the respective state regulatory threshold described in Table 1 (water temperature max. limit is 32°C; dissolved oxygen $\geq$ 5.0 mg/L; conductivity is $<2000 \mu\text{S/cm}$ and pH range is >6.5 or <9.0).

Table #3. Summary of descriptive statistics for water temperature, dissolved oxygen, specific conductance, and pH measured for the ice-free sampling period at Missouri National Recreational River in the Niobrara River from March 24 to December 15, 2021.

Descriptive Statistic	Water Temperature (°C)	Dissolved Oxygen (mg/L)	Specific Conductance ($\mu\text{S/cm}$)	pH
Mean	17.28	9.27	777.83	8.23
Standard Deviation	9.04	1.85	123.36	0.13
Median	18.7	8.7	750	8.2
Minimum	0	6.2	371	7.8
Maximum	37.9	14.2	1190	8.6
Number of Points	24665	24038	21944	24433
Number of Points below or Above Standard	943	0	0	0
Percent Exceedance	3.82%	0%	0%	0.00%

Table 4. Summary of monthly descriptive statistics and percent exceedances for core water quality parameters for the ice-free sampling period at Missouri National Recreational River in the Niobrara River from March 24 to December 15, 2021. Percent exceedance is the proportion of samples that exceed the respective state regulatory threshold described in Table 1 (water temperature max. limit is 32°C; dissolved oxygen $\geq$ 5.0 mg/L; conductivity is $<2000 \mu\text{S/cm}$ and pH range is >6.5 or <9.0).

Table #4. Summary of monthly descriptive statistics for water temperature, dissolved oxygen, specific conductance, and pH measured for the ice-free sampling period at Missouri National Recreational River in the Niobrara River from March 24 to December 15, 2021.

Dates	Descriptive Statistic	Water Temperature (°C)	Dissolved Oxygen (mg/L)	Specific Conductivity ($\mu\text{S/cm}$)	pH
March 24- March 31, 2021	Number of measurements	727	727	718	727
	Mean	8.57	10.89	1155.99	8.34

	Standard Deviation	2.75	0.75	28.46	0.07
	Median	8.5	10.8	1170	8.4
	Minimum	2.4	8.9	1060	8.1
	Maximum	16.9	13	1190	8.4
	% Exceedance	0.00%	0.00%	0.00%	0.00%
April, 2021	Number of measurements	2,024	2,016	1,922	2,021
	Mean	12.84	9.92	981.64	8.18
	Standard Deviation	4.6	1.03	174.01	0.11
	Median	12.6	9.9	1090	8.2
	Minimum	1.7	7.7	737	8
	Maximum	25.1	13.3	1180	8.4
	% Exceedance	0.00%	0.00%	0.00%	0.00%
May, 2021	Number of measurements	2,976	2,915	2,631	2,976
	Mean	17.44	8.97	789.27	8.12
	Standard Deviation	4.95	0.96	17.01	0.07
	Median	17.2	8.9	788	8.1
	Minimum	7.3	6.9	730	7.9
	Maximum	30.3	11.2	836	8.3
	% Exceedance	0.00%	0.00%	0.00%	0.00%
June, 2021	Number of measurements	2,879	2,866	2,588	2,879
	Mean	25.55	7.9	733.31	8.1
	Standard Deviation	4.6	0.69	20.12	0.08
	Median	25.1	7.9	734	8.1
	Minimum	14.7	6.6	652	7.9
	Maximum	35.4	9.8	786	8.2
	% Exceedance	10.59%	0.00%	0.00%	4.34%
July, 2021	Number of measurements	2,974	2,974	2,091	2,767
	Mean	26.23	7.78	729.53	8.17
	Standard Deviation	4.35	0.6	76.03	0.12
	Median	25.5	7.8	728	8.2
	Minimum	18.4	6.5	371	7.8
	Maximum	37.9	9.1	842	8.4
	% Exceedance	12.78%	0.00%	0.00%	0.00%
August, 2021	Number of measurements	2,973	2,813	2,927	2,971
	Mean	25.36	7.51	667.3	8.22

	Standard Deviation	4.3	0.58	29.9	0.08
	Median	24.8	7.5	669	8.2
	Minimum	16.4	6.2	517	8
	Maximum	35.3	9.1	736	8.4
	% Exceedance	8.68%	0.00%	0.00%	9.20%
September, 2021	Number of measurements	2,878	2,805	2,763	2,877
	Mean	20.58	8.41	713.26	8.24
	Standard Deviation	4.15	0.75	28.96	0.1
	Median	20.3	8.3	712	8.2
	Minimum	9.4	6.8	609	8
	Maximum	31.4	10.9	781	8.5
	% Exceedance	0.00%	0.00%	0.00%	0.43%
October , 2021	Number of measurements	2,966	2,965	2932	2,964
	Mean	13.04	9.91	737.84	8.28
	Standard Deviation	4.76	1.05	34.87	0.1
	Median	12.4	9.9	737	8.3
	Minimum	5	7.8	586	8.1
	Maximum	24.9	12.2	839	8.6
	% Exceedance	0.00%	0.00%	0.00%	0.55%
November, 2021	Number of measurements	2,886	2,579	2242	2,870
	Mean	5.07	12.04	818.65	8.42
	Standard Deviation	3.19	1.05	15.63	0.06
	Median	4.8	12	816	8.4
	Minimum	0	9.5	783	8.3
	Maximum	14.5	14.1	870	8.6
	% Exceedance	0.00%	0.00%	0.00%	0.55%
December 1-15, 2021	Number of measurements	1,382	1,378	1130	1,381
	Mean	1.91	12.94	822.45	8.38
	Standard Deviation	2.67	0.83	35.29	0.05
	Median	0	13.3	812	8.4
	Minimum	0	10.6	734	8.3
	Maximum	9.6	14.2	923	8.5
	% Exceedance	0.00%	0.00%	0.00%	0.00%

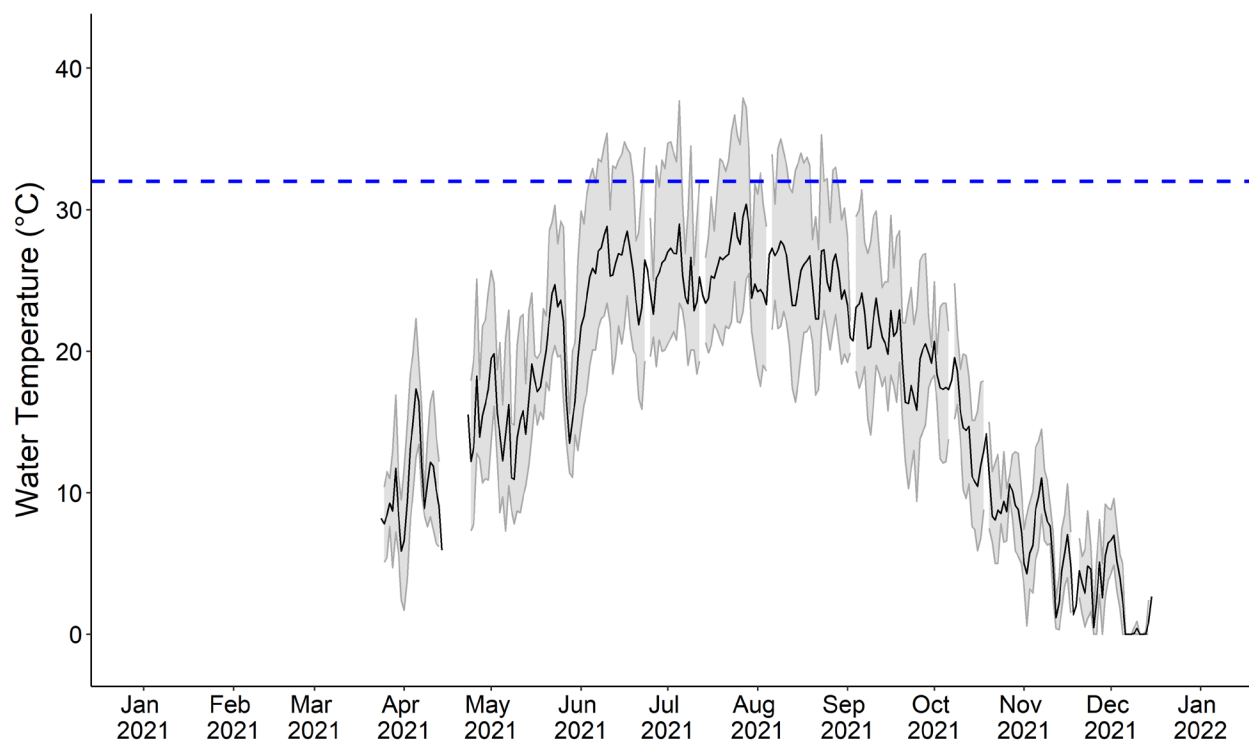


Figure 7. Daily mean water temperature (black line) collected on Bow Creek at Missouri National Recreational River in 2021. The sonde was in the water and recording data from March 24 through December 15, 2021. The gray ribbon shows the daily maximum and minimum water temperature for the same period. The dashed blue line indicates one of the Nebraska state water quality standards (see Table 1 for more details). The periods where the instrument did not collect data are indicated by gaps in the record.

Figure #7. Daily mean water temperature (black line) in 2021 on Bow Creek at Missouri National Recreational River, USGS Gaging station 06478522.

“Figure 7. Daily mean water temperature (black line) in 2021 on Bow Creek at Missouri National Recreational River, USGS Gaging station 06478522.”

Temperature displayed seasonal variation (Table 3, Figure 7). The highest mean temperatures were in the summer, averaging greater than 20°C in June, July, August, and September. Temperature strayed above state standards as the maximum temperature, 37.9°C, was above the state standard of 32°C and the total exceedance rate for the year was 3.82%.

Dissolved oxygen also displayed seasonal variation (Table 3, Figure 8). The highest mean dissolved oxygen concentrations were in the spring and fall, averaging greater than 9 mg/L in March, April, October, November, and December. Dissolved oxygen stayed below the state water quality criterion of 5 mg/L during 2021 (Table 1). 24,038 dissolved oxygen measurements were taken in 2021.

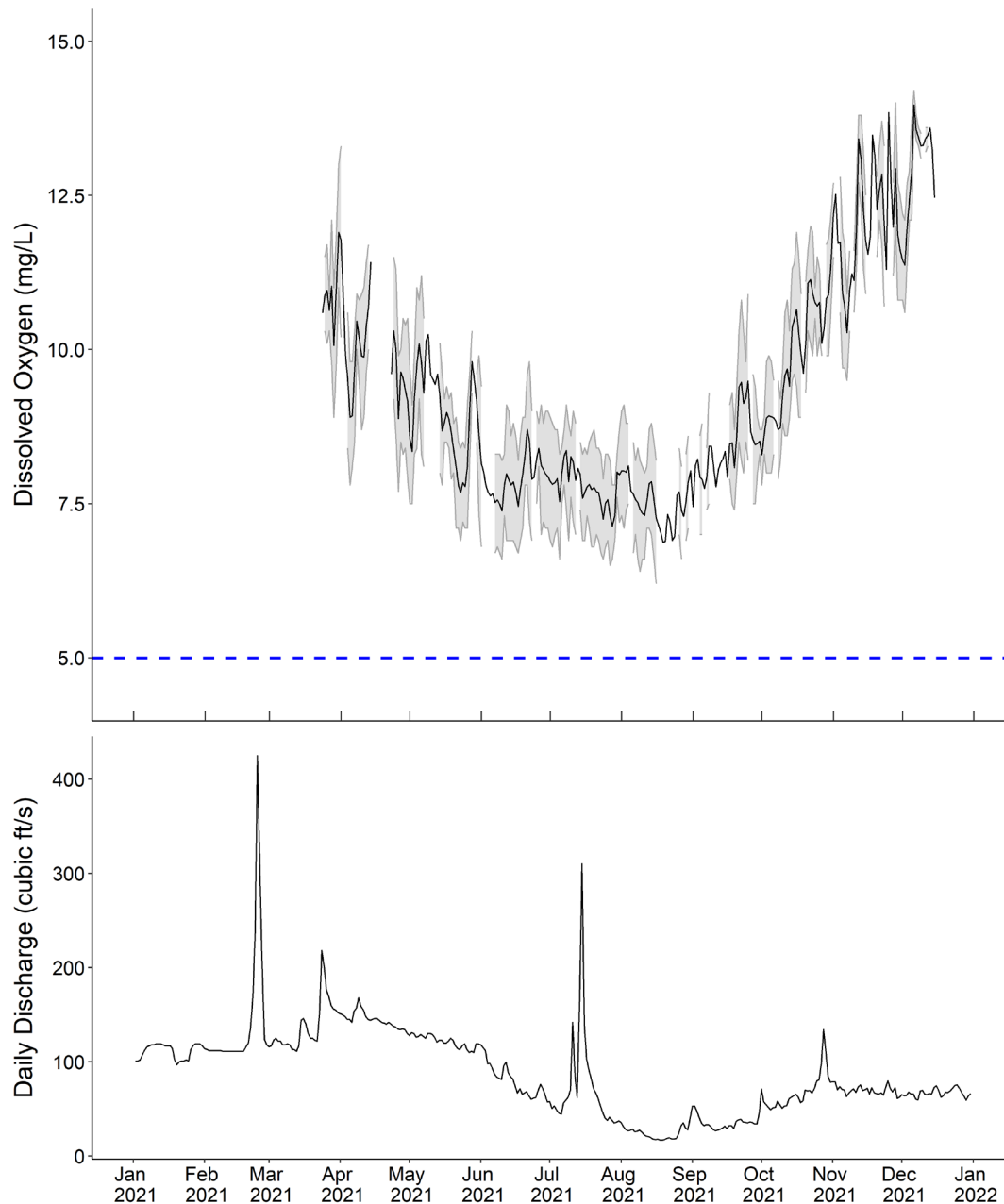


Figure 8. Daily mean dissolved oxygen concentrations (top) and daily discharge (bottom) of Bow Creek in 2021 at Missouri National Recreational River. Measurements were taken from March 24 through December 15, 2021. The gray ribbon shows the daily maximum and minimum dissolved oxygen for the same period. The dashed blue line indicates one of the Nebraska state water quality standards (see Table 1 for more details). The periods where the instrument did not collect data are indicated by gaps in the record.

Figure #8. Daily mean dissolved oxygen concentrations (top) and daily discharge (bottom) of Bow Creek in 2021 at Missouri National Recreational River.

“Figure 8. Daily mean dissolved oxygen concentrations (top) and daily discharge (bottom) of Bow Creek in 2021 at Missouri National Recreational River.”

Specific conductance of Bow Creek (Table 3, Figure 9) showed a less predictable seasonal pattern than temperature or dissolved oxygen concentrations. Values were moderately high for Northern Great Plains streams. Values above 2,000 $\mu\text{S}/\text{cm}$ are generally considered high though conductivity is very dependent on local geology and soil properties (Wilson, et al. 2014). The 2021 median specific conductance was 750 $\mu\text{S}/\text{cm}$, and ranged from 371-1190 $\mu\text{S}/\text{cm}$. The pH of the Niobrara River ranged between 7.8 and 8.6 (Figure 10), staying below the Nebraska state standard of 6.5 – 9.0.

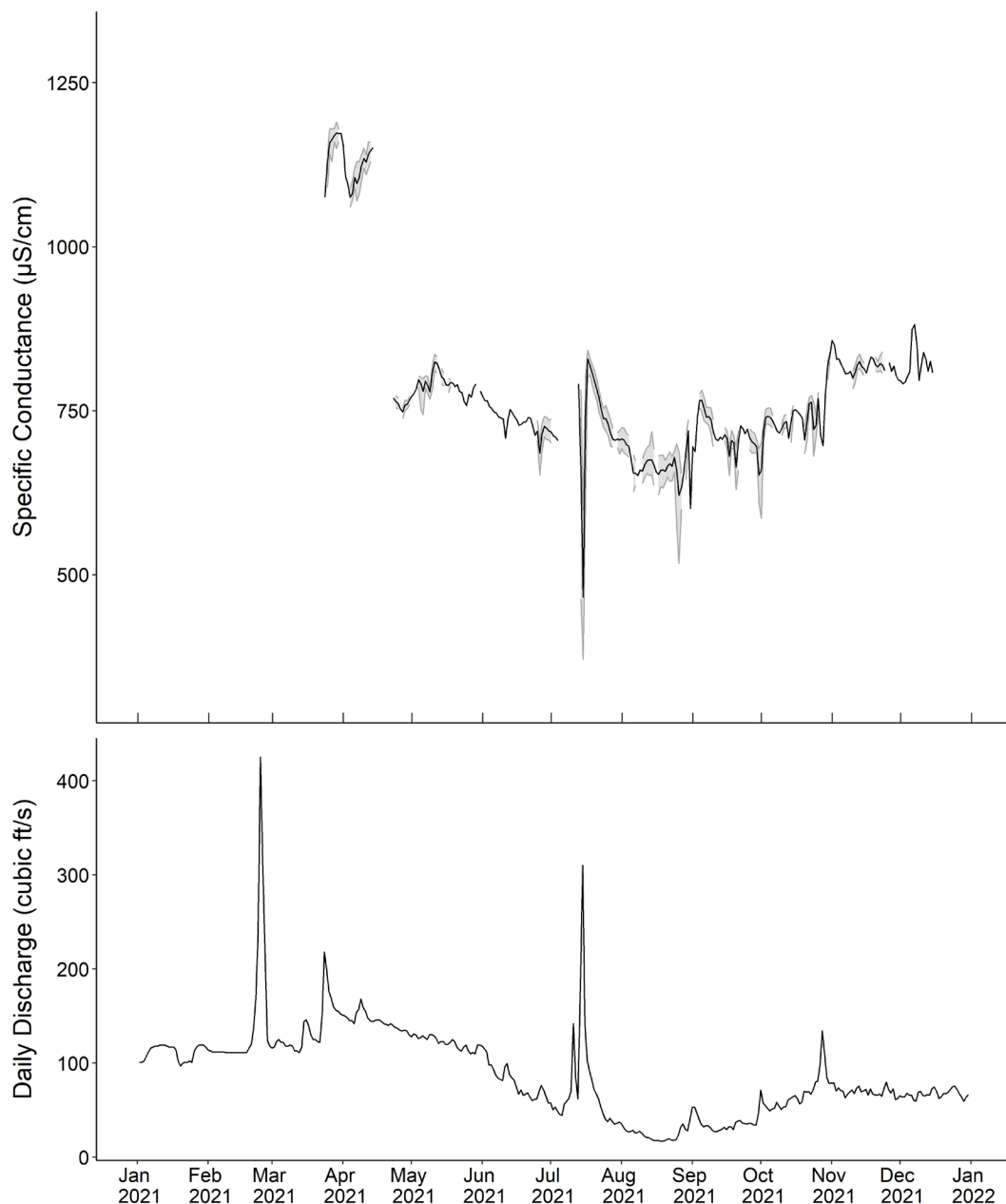


Figure 9. Daily mean specific conductance concentrations (top) and daily discharge (bottom) of Bow Creek in 2021 at Missouri National Recreational River. Measurements were taken from March 24 through December 15, 2021. The gray ribbon shows the daily maximum and minimum specific conductance for the same period. The dashed blue line indicates one of the Nebraska state water quality standards (see

Table 1 for more details). The periods where the instrument did not collect data are indicated by gaps in the record.

Figure #9. Daily mean specific conductance concentrations (top) and daily discharge (bottom) of Bow Creek in 2021 at Missouri National Recreational River.

“Figure 9. Daily mean specific conductance concentrations (top) and daily discharge (bottom) of Bow Creek in 2021 at Missouri National Recreational River.”

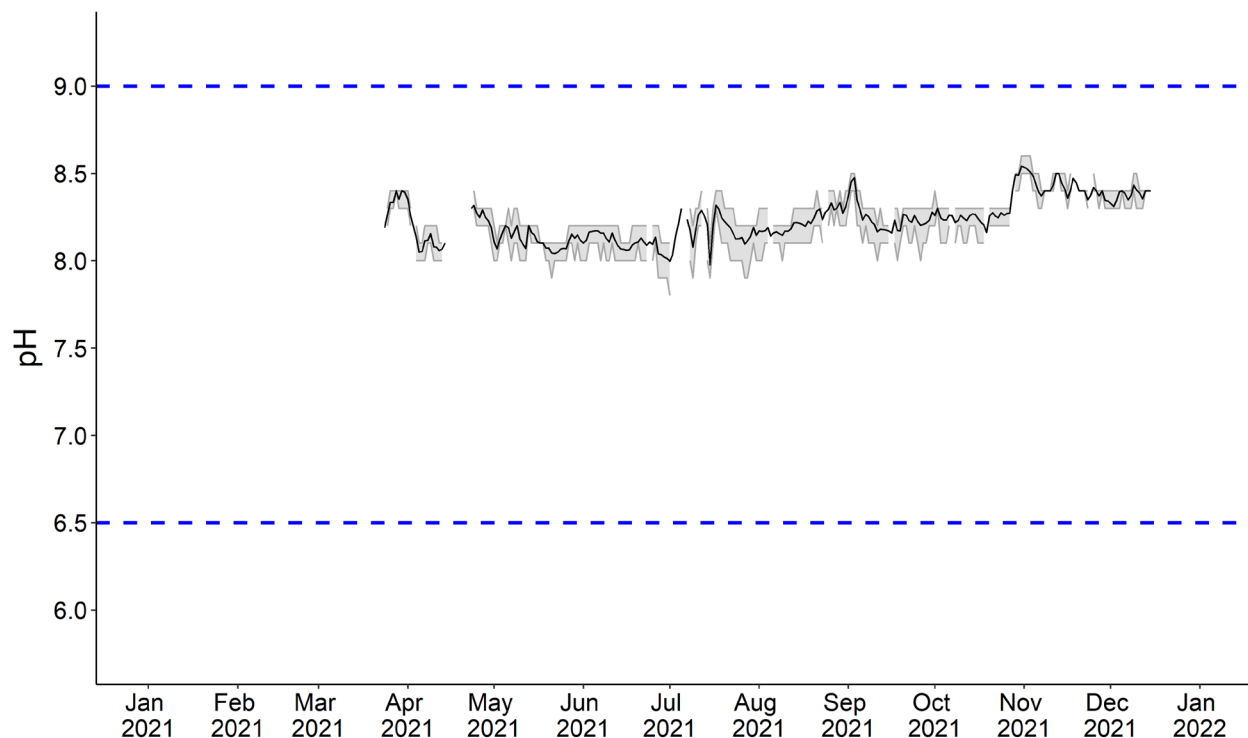


Figure 10. Daily mean pH levels (top) and daily discharge (bottom) of Bow Creek in 2021 at Missouri National Recreational River. Measurements were taken from March 24 through December 15, 2021. The gray ribbon shows the daily maximum and minimum pH for the same period. The dashed blue line indicates one of the Nebraska state water quality standards (see Table 1 for more details). The periods where the instrument did not collect data are indicated by gaps in the record.

Figure #10. Daily mean pH (top) and daily discharge (bottom) of Bow Creek in 2021 at Missouri National Recreational River.

“Figure 10. Daily mean pH (top) and daily discharge (bottom) of Bow Creek in 2021 at Missouri National Recreational River.”

Further Analysis

This report is intended to provide a basic review of the data collected during the 2021 water quality monitoring season at Bow Creek in Missouri National Recreational River. All data included in this

report is available upon request from the [Northern Great Plains Inventory and Monitoring Network](#), as well as in the archives found on the USGS National Water Information System, [Bow Creek near Wynot, Nebr. - USGS Water Data for the Nation](#).

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Appendix A. USGS Water Data Quality Findings and Station Analysis for Bow Creek, Wynot NE 0647855, 2021.

Water quality parameters were monitored on a continuous basis in a study performed at the USGS Bow Creek gage (06478522), located near Wynot, Nebraska on the Missouri National Recreation River during 2021. This was done to assess the current status and long-term trends of water quality on the Bow Creek near the Missouri River. This monitoring effort is identical to work performed in 2015 and 2018, and planned work for 2024.

The site was operated out of the USGS Nebraska office and visits were coordinated with the National Park Service's Missouri National Recreation River office. All water quality collected data for 2021, as well as prior year's water quality and stream data are available online. This includes any metadata and daily values. All data for this site can be retrieved at:
https://waterdata.usgs.gov/nwis/uv?site_no=06478522

The water quality monitor used for this site was an Exo multi-parameter sonde with four parameter capability of Specific Conductance, Dissolved Oxygen, pH, and water temperature. Data were collected every 15 minutes and reported hourly online. Data were collected during the deployed period of March 24th, 2021 to December 15th, 2021. The monitor was on hanging from the bridge 20' from the left bank for the first three weeks, then after April 14 the monitor was moved to a bank mounted position on the left bank under the bridge. The drier year frequently had depths across the entire channel less than 0.5ft deep. On several visits, the sonde was in the deepest part of the channel at 1.5ft deep.

13 field inspections were made during the ten-month deployment. At each of the inspections fouling-checks were made, and as needed instrument-drift checks were made. Fouling and calibration checks were made by cleaning the sonde and checking it to a reference field meter or standards. If a fouling or calibration correction was needed, the correction was prorated from last inspection. Corrections were compiled using Aquarius.

Water temperature data are rated as excellent. Some sand and stain fouling on the temperature probe was present. River flow past the instrument was able to keep the thermistor representative of the water in the entire channel. No corrections were needed to adjust the data because of this. The maximum water temperature observed was 37.9 deg C on July 27 and minimum temperature observed was 0.0 deg C on multiple occasions.

Specific conductance data are rated as fair. There was moderate fouling on the probe throughout the deployment period (stain fouling was the most common). Because of this influence of West Fork of Bow Creek and the movement of the sonde, the first part of the year before April 14 at times had different (typically higher) conductance values when compared to the rest of the year. All data prior to April 14 were downgraded to poor because of this. There was no apparent influence on any other parameter observed. The maximum specific conductance data point observed was 1190 uS/cm on March 31 and minimum conductance data point observed was 371 uS/cm on July 15.

Dissolved oxygen data are rated as good. There was stain fouling on the optical dissolved oxygen probe. This stain did not greatly impair the probe's ability to accurately monitor the stream. The central wiper was able to keep all forms of fouling off of the membrane a majority of the time and

keep the record relatively free of any large fouling corrections. The maximum dissolved oxygen data point observed was 14.2 mg/L on December 6 and minimum dissolved oxygen data point observed was 6.2 mg/L on August 19.

pH data are rated as excellent. There was minimal fouling on the pH probe throughout the deployment, resulting in minimal corrections. A few calibration corrections were needed on the probe throughout the year. The diurnal variations were likely due to temperature fluctuations and biological activity. The maximum pH data point observed was 8.6 std units on November 3 and minimum pH data point observed was 7.8 std units on July 1.