



Water Quality Monitoring for Theodore Roosevelt National Park

2016 Data Report

Natural Resource Data Series NPS/THRO/NRDS—2020/1265



**ON THIS PAGE**

Photograph of USGS Dakota Water Science Center water quality sonde location in the Little Missouri River near Medora, ND. Photograph courtesy of the National Park Service.

ON THE COVER

Photograph of Little Missouri River near Medora, ND, at Theodore Roosevelt National Park. Photograph by M. Wilson, courtesy of the National Park Service.

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2016 Data Report

Natural Resource Data Series NPS/THRO/NRDS—2020/1265

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The Natural Resource Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of those protocols

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Abstract

The Northern Great Plains Inventory and Monitoring Network (NGPN) began monitoring water quality in the Theodore Roosevelt National Park (THRO) in 2013, with the assistance of the U.S. Geological Survey (USGS). This report summarizes the data collected during the 2016 ice-free season (March 9 through November 2) for streamflow, water temperature, dissolved oxygen, specific conductance, and pH. This was the second season of continuous monitoring.

Compared to the first sampling period in 2013, 2016 was much drier and discharge on the Little Missouri River peaked at only 1440 cubic feet per second in late September. The highest flow in 2013 was over 8000 cubic feet per second. There was considerable seasonal variation in all water quality measures. A summary of our results can be found in Descriptive Statistics Summary tables for the ice-free season (Table 3) and for each month (Table 4). Notably, there were days when dissolved oxygen concentrations were below state standards and water temperatures and pH were above North Dakota standards. Water temperatures exceedances were the most common and temperatures above 29.4°C occurred 366 times or in 1.7 % of all records.

NGPN's collaboration with USGS supported real-time and archived access to this data through the USGS National Water Information System Website, where it remains available to the public.

Introduction

Located in southwestern North Dakota, Theodore Roosevelt National Park (THRO) encompasses of 70,477 acres in the Little Missouri Badlands. THRO is composed of three discrete management units, each of which is a patchwork of mixed-grass prairie, clay buttes, bottomland forest, and open shrublands. The three park units (North, Elkhorn Ranch, and South) are connected by the Little Missouri River, an undammed tributary of the Missouri River with headwaters located in northeastern Wyoming, making it the major hydrologic feature for THRO. The Little Missouri flows for approximately 560 miles from south to north through parts of Wyoming, Montana, South Dakota and the badlands of North Dakota, and approximately 28 miles run through the park (Figure 1). The 269 miles of intermittent streams within the park provide substantial flow to the Little Missouri River during spring snowmelt and summer rainfall events (Gitzen et al. 2010).

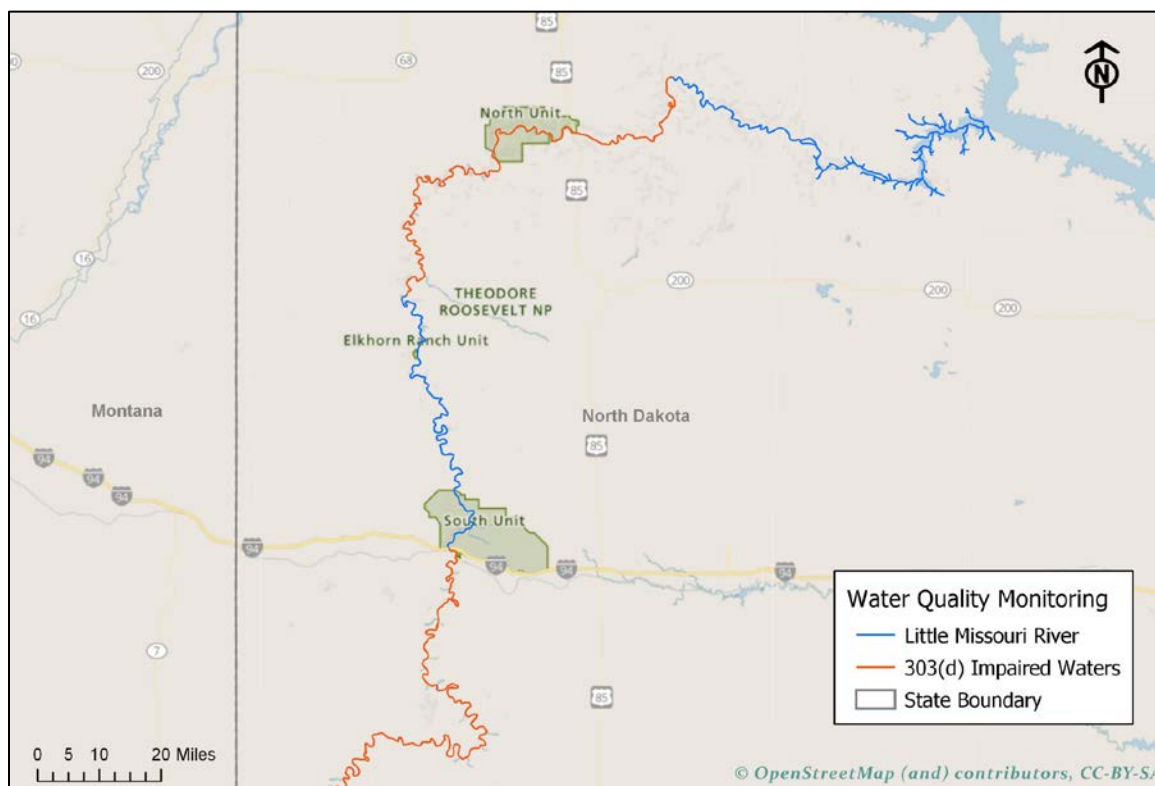


Figure 1. Map of Theodore Roosevelt National Park and the Little Missouri River in North Dakota. The stretch of the river running through the North Unit, is listed as impaired under 303(d) criteria (indicated in red) for *Escherichia coli*.

The Little Missouri River is designated as a Class II water in North Dakota. Class II waters are similar to Class I which are defined as “water suitable for propagation or protection, or both, of resident fish species and other aquatic biota and for swimming, boating and other water recreation”, but for Class II additional treatment may be required to meet drinking water requirements (NDDEQ 2019). The stretch of the Little Missouri that runs through the North Unit is listed as an impaired

waterway under section 303(d) of the Clean Water Act for exceedances of *Escherichia coli* (ND Department of Health 2019). A small part of the Little Missouri River within the THRO South Unit boundary (Figure 1) is also listed as impaired for *E. coli*. The source of the *E. coli* and fecal coliform is not known, but livestock feeding operations, agriculture, and failing septic systems are likely contributors. For more details and current impairment information visit the [North Dakota Department of Environmental Quality website](#).

The Northern Great Plains Inventory & Monitoring Network (NGPN) began monitoring water quality at THRO in 2013 to better understand current conditions and changes over time in the Little Missouri River (Rockwood and Ashton 2020). The monitoring is conducted at the gaging station at Medora, ND (Monitoring Location 06336000, Figure 2) in collaboration with the United States Geological Survey (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 THRO every three years, starting in 2013 (Wilson et al. 2014), conducting in-depth analysis of status and trends after 3 to 5 cycles of sampling.

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 April to October), and results are made available in real-time on the USGS National Water Information System Website.

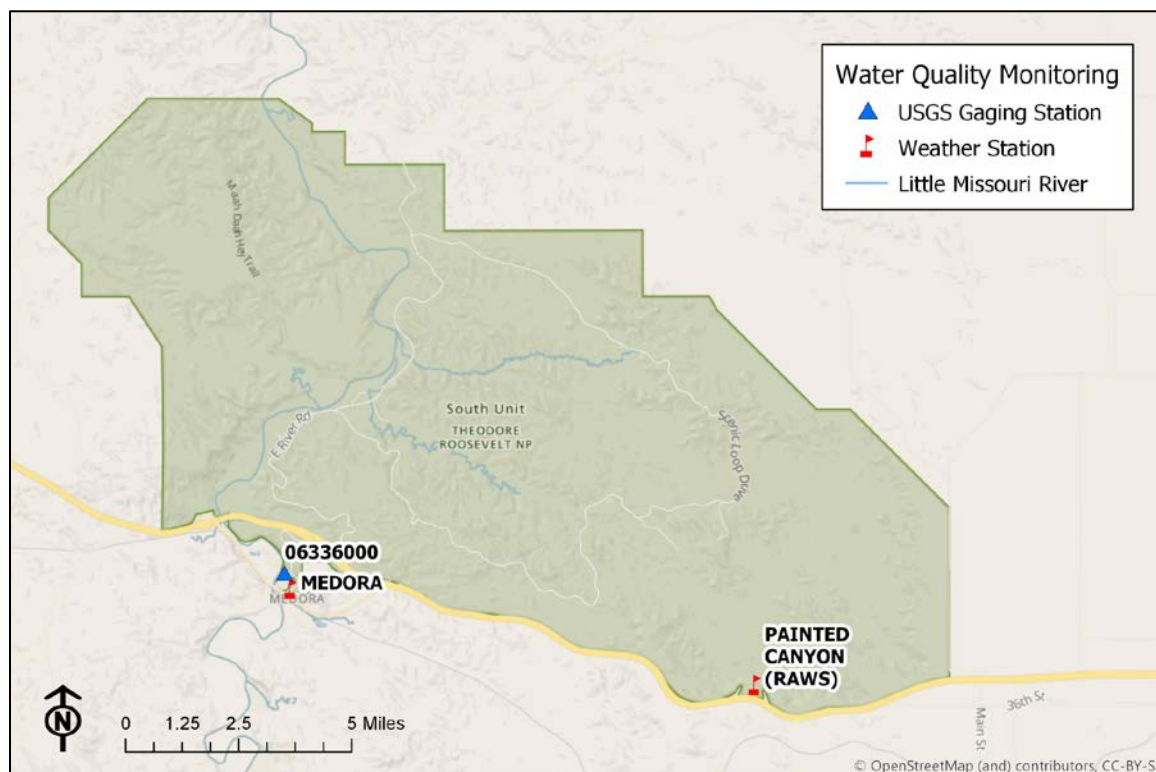


Figure 2. Map of Theodore Roosevelt National Park and water quality monitoring location (blue triangle) and nearby weather station (red flags). Climate data in this report is taken from the Painted Canyon RAWS weather station.

Table 1. Water quality parameters measured as part of the Northern Great Plains Inventory & Monitoring Water Quality Program and associated state standards for North Dakota class II waters (NDDEQ 2019).

Water Quality Parameter	Description	ND 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 and reflectance and land use/cover in the watershed.	• 29.44°C • The maximum increase shall not be greater than five degrees 2.78°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.	• 5 mg/l as a daily minimum • up to 10% of representative samples collected during any 3-year period may be less than this value provided that lethal conditions are avoided
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.	No criteria
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.	• 6.0 - 9.0 • up to 10% of representative samples collected during any 3-year period may exceed this range, provided that lethal conditions are avoided.

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 06336000) in Medora, ND, at around 2248 ft elevation. Water quality and streamflow are measured every 15 minutes throughout the ice-free season. Monitoring at THRO began in 2013, was repeated in 2016, and will be repeated every three years thereafter. Program funding currently limits monitoring to a cycle of one year of monitoring, followed by two years without.

In 2016, NGPN partnered with the USGS North Dakota Water Science Center to have USGS staff collect water quality and streamflow data at THRO. The USGS deployed a continuous, multi-parameter sonde at the Little Missouri River Gaging Station (06336000) near Medora, ND, on March 9, 2016, (Figure 3) and visited the gaging station every 3-4 weeks for equipment maintenance (Table 2). The sonde instrument recorded dissolved oxygen (DO), pH, specific conductivity, and water temperature every 15 minutes, while the gage simultaneously measured stream stage (gage height; measured in feet) and discharge, a measure of streamflow.



Figure 3. A sonde device is used to measure water quality in the Little Missouri River at Theodore Roosevelt National Park (right panel). The United States Geological Survey Little Missouri gaging station (06336000) is set up for real-time data transmission via satellite (left panel). Photographs courtesy of NPS.

Satellite telemetry transmitted the water data to the Water Science Center in near real-time (<https://waterdata.usgs.gov/monitoring-location/06336000/>). 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 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. Calibration included pre- and post-calibration checks to quantify fouling errors and equipment drift – data critical to correction and grading of the final data. On November 2, 2016, the USGS removed the multi-parameter sonde from the Little Missouri River.

Quality assurance and quality control was conducted by USGS staff following established USGS guidelines (Wagner et al. 2006). NGPN received the final corrected (approved) data in February of 2017 from the USGS, and used AQUARIUS Workstation by Aquatic Informatics (<http://aquaticinformatics.com/>) and R (R Core Team 2019) to store and analyze 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 15-minute interval data. In the case where there were missing data due to instrument error, means were generated by excluding the missing values and the maximum and minimum were left blank. Means were not calculated for days where all time steps were missing (i.e. the instrument didn't collect any data that day). We calculated the proportion of records that exceeded North Dakota environmental regulatory thresholds (Table 1).

Climate data were downloaded from the Painted Canyon RAWS climate station. The data were accessed and graphed using the web-based tool [Climate Analyzer](#).

Table 2. Field journal for 2016 Water Quality Sampling at Theodore Roosevelt National Park.

Date	Notes
March 9, 2016	Installed YSI monitor on left bank upstream, ~ 12 pm. Short cable for probe installed as far in channel as possible. Orifice cut on arrival, fixed in field.
March 22, 2016	Moved QW probe into deeper pool. Orifice still good, and gage tracking good.
April 12, 2016	Service visit. DO not working; replaced monitor with new one; recalibration readings are from the new monitor. Sensors with slight amount of mud; wiper missing
May 5, 2016	Serviced QW monitor. Orifice fence post was bent over. Discharge measurement collected just above drainage channel, upstream of railroad bridge – flow too low at bridge to use ADCP (acoustic doppler current profiler).
May 12, 2016	Checked gage, cleaned probe. Orifice checked and still solid but may need to be relocated due to falling gage-heights. Some sand bars forming downstream of the gage.
May 19, 2016	Checked calibration on sensor – recalibrated pH to 7.1, no other resets. Some chewing has occurred on sensor guard. Water low, and sensor will be out of water if a drop occurs. Cable too short to move further into stream.
June 8, 2016	Calibration check on water quality meter – recalibrated DO, no resets. Replaced 50ft cable with 200ft cable to place orifice further into the stream.
June 28, 2016	Checked multi-parameter meter. Recalibrated DO (wiper was missing) and pH (to 10.0). No resets. Silt and light debris on sensors.
July 11, 2016	Photos taken. Water too low again at bridge to use ADCP for discharge measurement; used AA meter instead.
July 19, 2016	Checked calibration on multi-parameter meter; no resets. Debris build up on fence post was removed. Sensors filled with sediment. Wiper on DO still missing.
July 29, 2016	Dug out and cleaned multi-parameter meter. No calibration checks. Reestablished temperature orifice due to silting in.
August 17, 2016	Routine measurements. Removed some debris from fence post mount.
August 26, 2016	Checked multi-parameter meter and recalibrated pH. Sensors cleared of silt.
September 16, 2016	Checked multi-parameter meter; no resets. Lots of debris on fence post where orifice is mounted – cleared off; fence post may have moved due to pressure from water on debris.
September 27, 2016	Made a bridge board high flow measurement – peak flow hit, and levels coming down. Verification probe readings taken; could not reach installed probe for cleaning.
October 5, 2016	Switched live meter with field meter (new sonde installed) – heavy debris on sensors, which cracked pH probe. Silt on DO wiper.
November 2, 2016	Serviced sensors – cleared sticks and silt from sensors. Current water stage at high-water mark (2.01 ft). Removed multi-parameter probe ~12:50 pm.

Results

The water quality monitoring season (ice-free) on the Little Missouri River at THRO lasted from March 9, 2016 to November 2, 2016 (Figure 4). River discharge was low in the beginning of the monitoring periods and then increased periodically throughout the season. The maximum recorded daily discharge was recorded on September 27, 2016 at 1400 cubic feet per second. In comparison to past years, 2016 water year was drier but there was over 4 inches of precipitation in September (Figure 5). It rained and snowed a total of 16.18 inches in 2016.

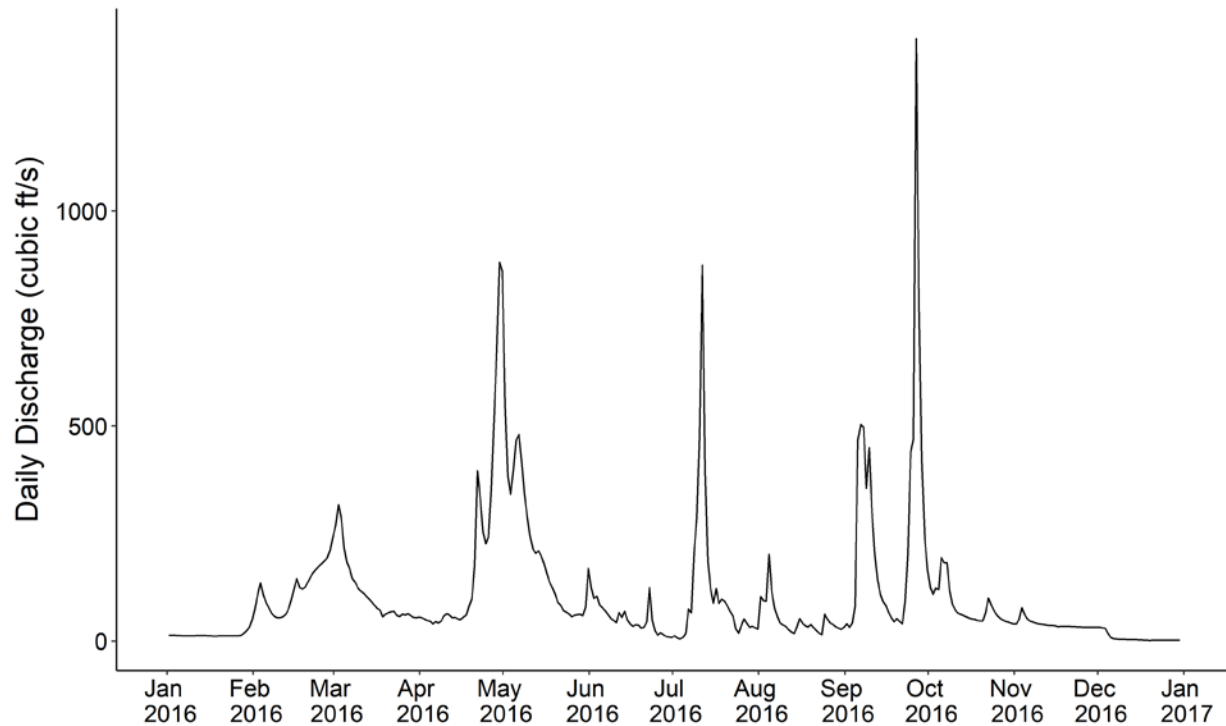


Figure 4. Daily mean discharge on the Little Missouri River at Theodore Roosevelt National Park from March 9 to November 2, 2016, at USGS Gaging Station 06336000.

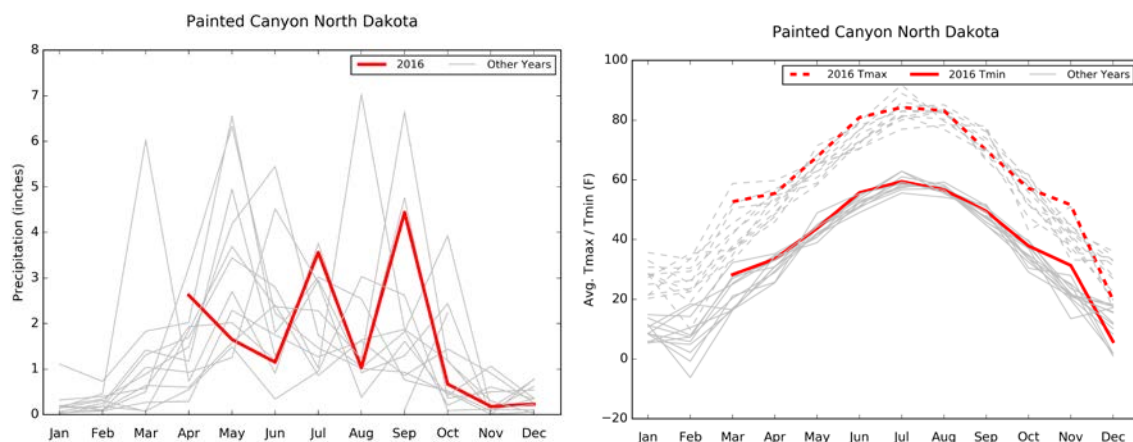
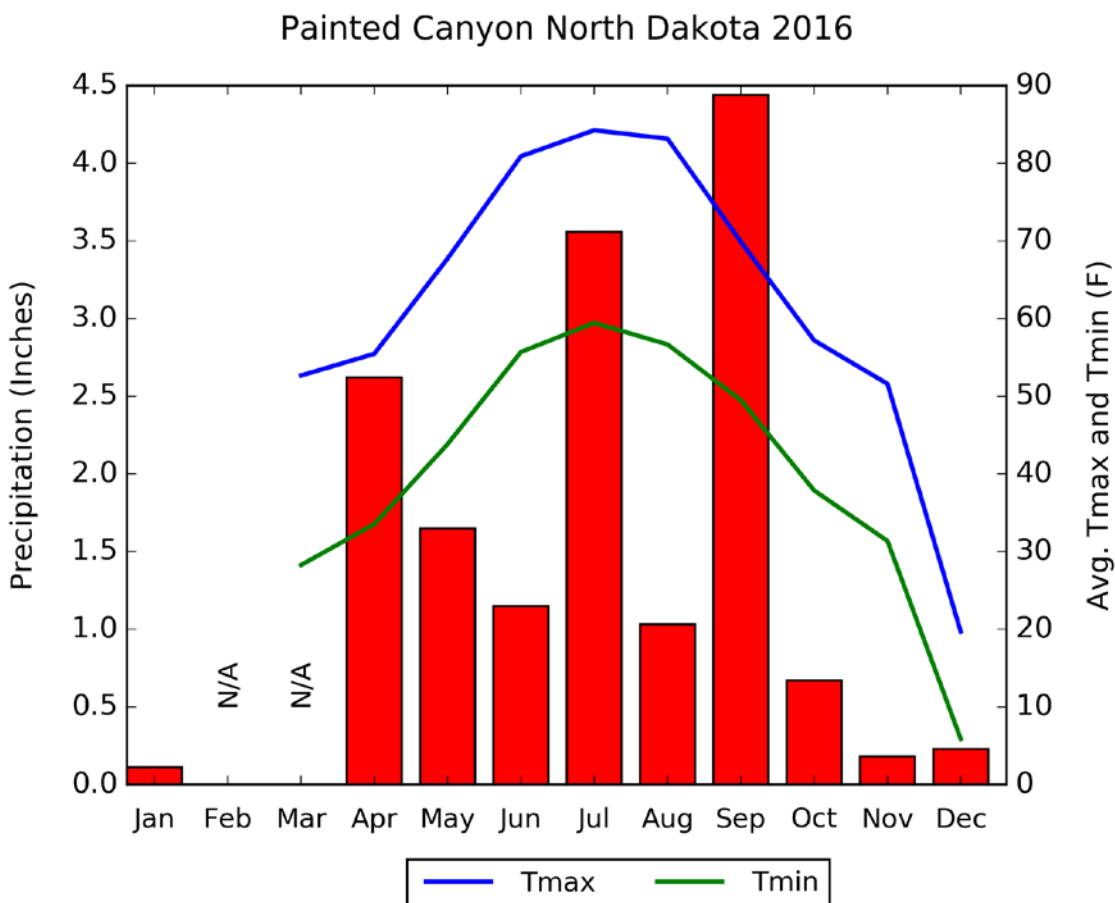


Figure 5. Total monthly precipitation (green) and average monthly minimum (blue) and maximum (red) temperature for the 2016 water year in Theodore Roosevelt National Park (top panel). A comparison of 2016 precipitation (bottom left) and temperature (bottom right) in Theodore Roosevelt National Park compared to the period of record. Climate data are from Painted Canyon RAWs climate station. The data were accessed and graphed using the web-based tool [Climate Analyzer](#).

During the ice-free season at THRO, we collected over 20,000 water quality measurements in the Little Missouri River (Table 3). We found mean water temperature of 15.75°C, dissolved oxygen

concentrations of 8.76 mg/L, specific conductance of 1966, and pH of 8.26 (Table 3). There was, however, variation across months in all parameters (Table 4). Mean water temperature in March was 6.9°C and increased to a mean of close to 25°C in July before declining back to 3.2°C in October (Table 4, Figure 6). Maximum temperatures exceeded the North Dakota water quality standard of 29.4°C (Table 1) 366 times, or in 1.77% of records (Table 4). Exceedances were primarily in the month of June and July (Table 4, Figure 6).

Table 3. Summary of descriptive statistics for water temperature, dissolved oxygen, specific conductance, and pH measured for the ice-free sampling period on the Little Missouri River at Theodore Roosevelt National Park from March 9 to November 2, 2016, at USGS Gaging Station 06336000. Percent exceedance is the proportion of samples that exceed the respective state regulatory threshold described in Table 1 (water temperature max. limit is 29.4°C; dissolved oxygen $\geq$ 5.0 mg/L and pH range is <6.0 or >9.0).

Descriptive Statistic	Water Temperature (°C)	Dissolved Oxygen (mg/L)	Specific Conductance (μ S/cm)	pH
Mean	15.75	8.76	1966.81	8.26
Standard Deviation	6.86	1.3	574.13	0.37
Median	15.8	8.6	1920	8.3
Minimum	-0.1	4.7	583	7.1
Maximum	34.3	13.1	3370	9.1
Number of Points	20706	15524	20113	18588
Number of Points below or above standard	366 (above)	7 (below)	–	41 (above) 0 (below)
% Exceedance	1.77%	0.05%	–	0.22%

Table 4. Monthly summary of descriptive statistics and percent exceedances for core water quality parameters for the ice-free sampling period at Little Missouri River at Theodore Roosevelt National Park from March 9 to November 2, 2016, at USGS Gaging Station 06336000. Percent exceedance is the proportion of samples that exceed the respective state regulatory threshold described in Table 1 (water temperature max. limit is 29.4°C; dissolved oxygen $\geq$ 5.0 mg/L and pH range is <6.0 or >9.0).

Dates	Descriptive Statistic	Water Temperature (°C)	Dissolved Oxygen (mg/L)	Specific Conductivity (µS/cm)	pH
March 9-31, 2016	Number of measurements	1440	0	964	1440
	Mean	6.89	–	2625.1	8.66
	Standard Deviation	2.65	–	94.81	0.06
	Median	7	–	2650	8.7
	Minimum	-0.1	–	2330	8.5
	Maximum	12.9	–	2740	8.8
	% Exceedance	0	–	–	0
April, 2016	Number of measurements	2876	1530	2876	2876
	Mean	9.53	9.95	2492.4	8.28
	Standard Deviation	3.69	0.98	343.51	0.33
	Median	9	9.9	2670	8.2
	Minimum	2.1	8.2	1570	7.7
	Maximum	18	11.7	2930	8.9
	% Exceedance	0	0	–	0
May, 2016	Number of measurements	2971	1820	2875	2008
	Mean	16.21	8.65	1843.38	8.27
	Standard Deviation	3.84	0.74	226.39	0.27
	Median	16.4	8.5	1810	8.2
	Minimum	7	7.2	1480	7.7
	Maximum	25.4	10.7	2200	8.7
	% Exceedance	0	0	–	0
June, 2016	Number of measurements	2875	2114	2866	2392
	Mean	22.24	7.85	2394.54	8.26
	Standard Deviation	3.98	0.74	331.61	0.35
	Median	21.8	7.7	2355	8.3
	Minimum	11.5	6.1	1710	7.3
	Maximum	31.9	9.9	2980	9.1
	% Exceedance	3.93%	0	–	0.08%

Table 4 (continued). Monthly summary of descriptive statistics and percent exceedances for core water quality parameters for the ice-free sampling period at Little Missouri River at Theodore Roosevelt National Park from March 9 to November 2, 2016, at USGS Gaging Station 06336000. Percent exceedance is the proportion of samples that exceed the respective state regulatory threshold described in Table 1 (water temperature max. limit is 29.4°C; dissolved oxygen $\geq$ 5.0 mg/L and pH range is <6.0 or >9.0).

Dates	Descriptive Statistic	Water Temperature (°C)	Dissolved Oxygen (mg/L)	Specific Conductivity (µS/cm)	pH
July, 2016	Number of measurements	1632	1152	1626	1152
	Mean	24.56	7.56	2391.47	7.82
	Standard Deviation	4.19	0.63	606.04	0.22
	Median	24.3	7.5	2200	7.8
	Minimum	16	6.4	1410	7.3
	Maximum	34.3	9	3370	8.3
	% Exceedance	14.09%	0	–	0
August, 2016	Number of measurements	2973	2973	2970	2973
	Mean	21.65	7.99	1836.8	8.03
	Standard Deviation	3.63	1.25	258.15	0.56
	Median	21.6	7.8	1810	7.9
	Minimum	13.7	5.5	1350	7.1
	Maximum	31.2	13.1	2460	9.1
	% Exceedance	0.77%	–	–	0.81%
September, 2016	Number of measurements	2877	2874	2874	2685
	Mean	15.46	8.55	1292.1	8.33
	Standard Deviation	2.76	0.69	492.2	0.25
	Median	15.1	8.6	1120	8.3
	Minimum	9.9	4.7	583	7.9
	Maximum	24.6	9.9	2610	9.1
	% Exceedance	0	0.24%	–	0.56%
October, 2016	Number of measurements	9.05	10.23	1499.06	8.39
	Mean	3.24	0.8	287.88	0.09
	Standard Deviation	8.5	10.3	1480	8.4
	Median	2.7	8.1	942	8
	Minimum	20.1	11.8	2000	8.6
	Maximum	9.05	10.23	1499.06	8.39
	% Exceedance	0	0	–	0

Table 4 (continued). Monthly summary of descriptive statistics and percent exceedances for core water quality parameters for the ice-free sampling period at Little Missouri River at Theodore Roosevelt National Park from March 9 to November 2, 2016, at USGS Gaging Station 06336000. Percent exceedance is the proportion of samples that exceed the respective state regulatory threshold described in Table 1 (water temperature max. limit is 29.4°C; dissolved oxygen ≥ 5.0 mg/L and pH range is <6.0 or >9.0).

Dates	Descriptive Statistic	Water Temperature (°C)	Dissolved Oxygen (mg/L)	Specific Conductivity ($\mu\text{S/cm}$)	pH
November 1-2, 2016	Number of measurements	92	92	92	92
	Mean	8.9	10.18	2039.67	8.4
	Standard Deviation	1.28	0.25	20.94	0
	Median	8.6	10.1	2040	8.4
	Minimum	7.2	9.9	2000	8.4
	Maximum	11.1	10.6	2070	8.4
	% Exceedance	0	0	–	0

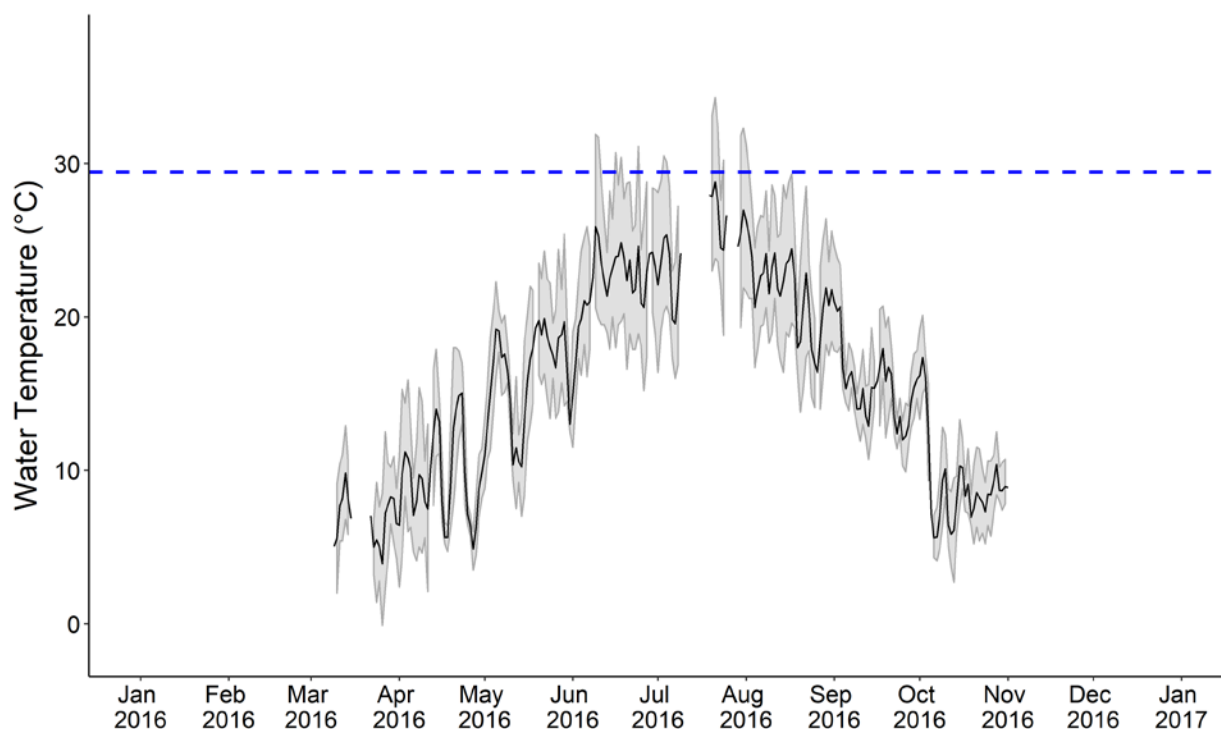


Figure 6. Daily mean water temperature (black line) collected on the Little Missouri River at Theodore Roosevelt National Park from March 9 to November 2, 2016, at USGS Gaging Station 06336000. The gray ribbon shows the daily maximum and minimum water temperature for the same period. The dashed blue line indicates one of the North Dakota 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.

Dissolved oxygen also displayed seasonal variation (Table 3, Figure 7). The highest mean dissolved oxygen concentrations were in the spring and fall, averaging greater than 10 mg/ L in October and November. Dissolved oxygen was found below the North Dakota state water quality criteria (Table 1). Dissolved oxygen concentrations measured below 5 mg/ L in the Little Missouri River 7 times in September (Table 3, Figure 7).

Specific conductance of the Little Missouri River was highly variable throughout the year (Table 3, Figure 8), but showed a less predictable seasonal pattern than temperature or dissolved oxygen concentrations. The pH of the Little Missouri River ranged between 7.1 and 9.1 (Figure 9) and was above the North Dakota state standards a few times in September.

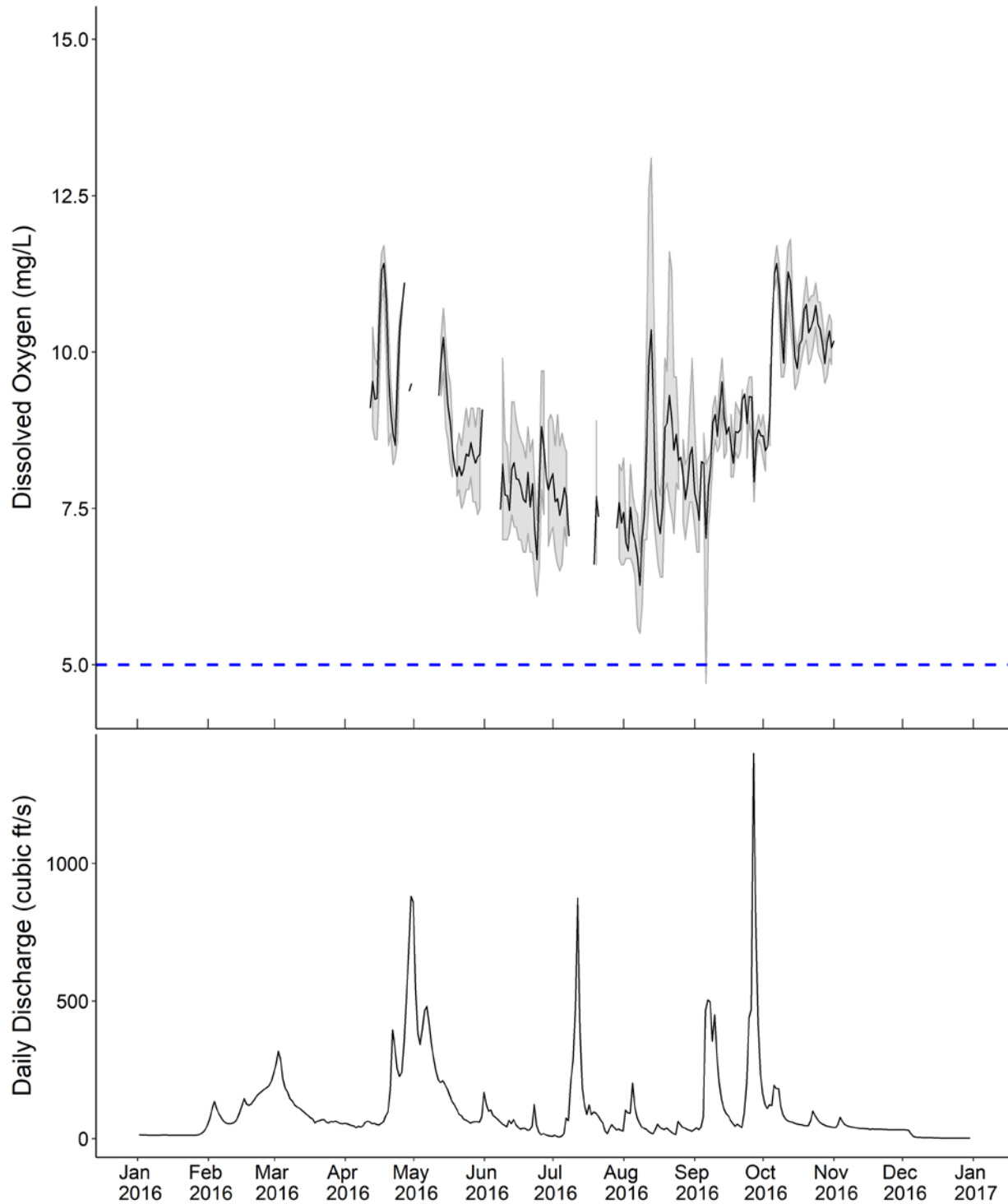


Figure 7. Daily mean dissolved oxygen concentrations (top) and daily discharge (bottom) of the Little Missouri River at Theodore Roosevelt National Park from March 9 to November 2, 2016, at USGS Gaging Station 06336000. The gray ribbon shows the daily maximum and minimum dissolved oxygen for the same period. The dashed blue line indicates one of the North Dakota 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.

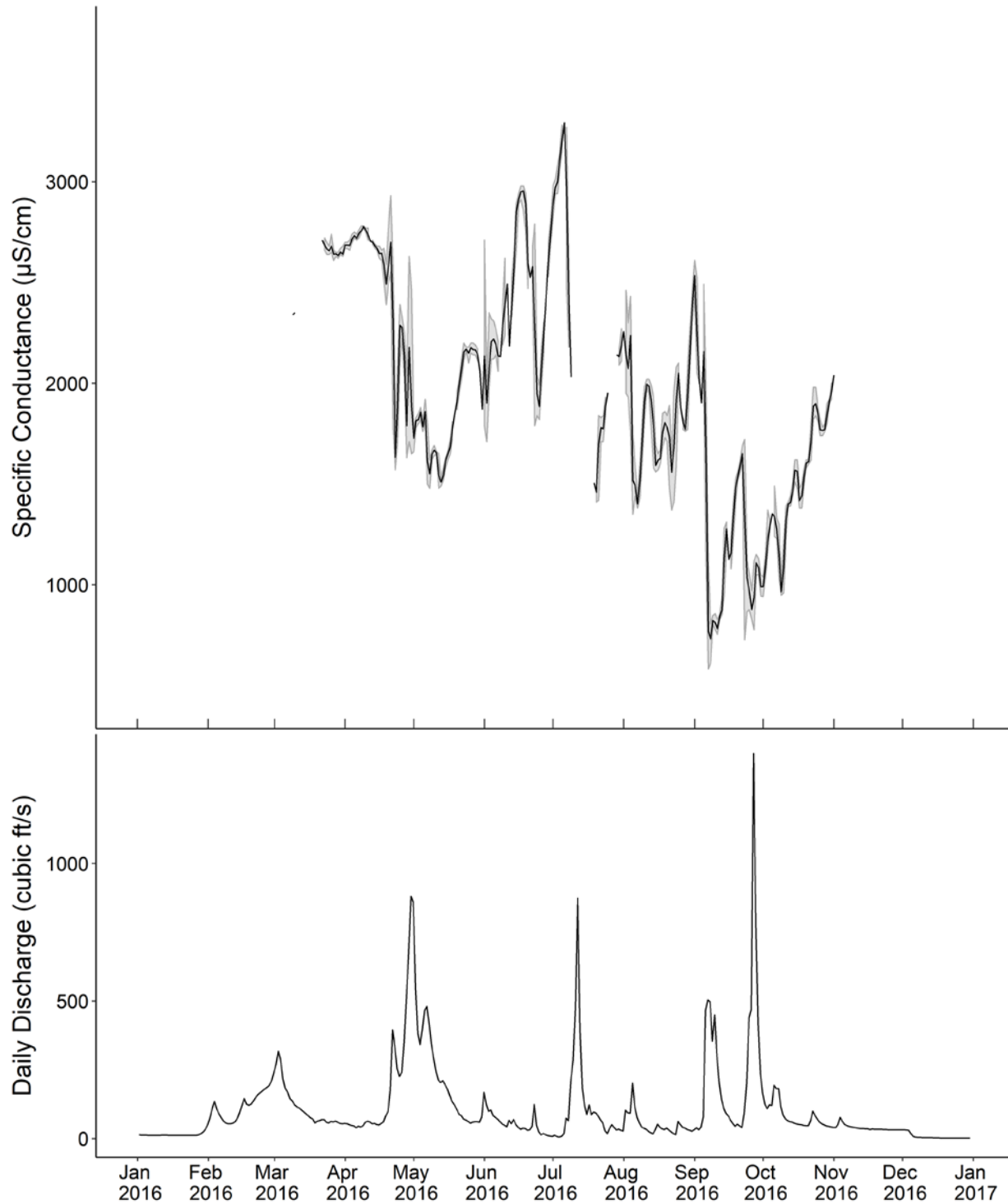


Figure 8. Daily mean specific conductance (top) and daily discharge (bottom) of the Little Missouri River at Theodore Roosevelt National Park from March 9 to November 2, 2016, at USGS Gaging Station 06336000. The gray ribbon shows the daily maximum and minimum specific conductivity for the same period. The periods where the instrument did not collect data are indicated by gaps in the record.



Figure 9. Daily mean pH (black line) of the Little Missouri River at Theodore Roosevelt National Park from March 9 to November 2, 2016, at USGS Gaging Station 06336000. The gray ribbon shows the daily maximum and minimum pH for the same period. The dashed blue lines indicate the North Dakota 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.

Further Analysis

This Data Report is intended to provide a basic review of the data collected during the 2016 water quality monitoring season at Theodore Roosevelt National Park. 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 for site 06336000](#).

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Appendix A. USGS Water Data Quality Report for Little Missouri River 06336000, 2016

06336000 LITTLE MISSOURI RIVER AT MEDORA, ND

LOCATION - Lat 46°55'05.06", long 103°31'49.24" referenced to North American Datum of 1983, in T.140 N., R.102 W., Billings County, ND, Hydrologic Unit 10110203, on left bank 50 ft above bridge on U.S. Highway 10, one quarter of a mi west of Medora, and 1 1/4 mi upstream from Andrews Creek.

DRAINAGE AREA - 6,190 mi², approximately.

[REVISIONS HISTORY](#) - WSP 546: Drainage area. WSP 1279: 1903-7, 1923-24, 1930-31, 1934(M). When the gage was re-established in March 2001, the base gage was incorrectly set 0.84 ft too low. All gage heights since October 1, 2002, and the 2001 peak stage have been corrected. Unit values and daily values data for water years 2001-02 have not been adjusted. Discharge data for those years are unaffected by this correction.

SURFACE-WATER RECORDS

PERIOD OF RECORD - DAILY DISCHARGE--May 1903 to October 1908, October to November 1921, April, May, and December 1922, May 1923 to September 1924, October 1928 to September 1934, October 1945 to September 1975, March 2001 to current year. Monthly discharge only for some periods, published in WSP 1309.

PERIOD OF RECORD--DAILY GAGE HEIGHT--August 2001 to current year.

GAGE - Water-stage recorder on upstream side of highway bridge. Datum of gage is 2248.44 ft above North American Vertical Datum of 1988 (NAVD88). National Geodetic Vertical Datum of 1929 (NGVD29) datum was converted to NAVD88 datum using the National Geodetic Surveys VDATUM transformation tool in November, 2017. Prior to October 1, 2017, datum was published as 2,246.75 ft above the NGVD29. September 1951 to September 1975, recording gage 600 feet downstream at current datum. October 9, 1945, to August 22, 1951, non-recording gage at current location at current datum. Prior to October 9, 1945, non-recording gages at several sites within 0.2 miles upstream from present site at various datums.

REMARKS - Accuracy of records for water years prior to 2014 are noted in the individual Annual Data Reports for those water years. For water years 2014 onward, records good except for estimated discharges, which are poor, unless otherwise noted.

WATER-QUALITY RECORDS

PERIOD OF DAILY RECORD -

WATER TEMPERATURE: March 1947 to September 1949, April to November 2013, March to November 2016 (discontinued).

SPECIFIC CONDUCTANCE: April to November 2013, March to November 2016 (discontinued).

PH: April to November 2013, March to November 2016 (discontinued).

DISSOLVED OXYGEN: April to November 2013, March to November 2016 (discontinued).

INSTRUMENTATION - Multiparameter waterquality monitor.

REMARKS -

RECORD RATED - WATER TEMPERATURE:

Period April 6-November 5, 2013: Rated good: April 6-November 5.

Period March 9-November 2, 2016: Rated good: March 9-November 2.

RECORD RATED - SPECIFIC CONDUCTANCE:

Period April 6-November 5, 2013: Rated good: May 14-August 12, September 17-November 5. Rated fair: April 6-May 13. Rated poor: August 13-September 16.

Period March 9-November 2, 2016: Rated good: March 9-August 16, August 27-31, September 17-21, October 6-November 2: Rated fair August 17-26, September 1-3: Rated poor September 4-12, September 25-October 3.

RECORD RATED - PH:

Period April 6-November 5, 2013: Rated good: April 6-July 10, July 17-August 9, August 14-November 5. Rated fair: July 11-16, August 10-13.

Period March 9-November 2, 2016: Rated good: March 9-November 2.

RECORD RATED - DISSOLVED OXYGEN:

Period April 6-November 5, 2013: Rated good: April 6-November 5.

Period March 9-November 2, 2016: Rated good: March 9-November 2.

EXTREMES FOR PERIOD - APRIL 6-NOVEMBER 5, 2013:

WATER TEMPERATURE: Maximum recorded, 30.4°C, September 6; minimum recorded, -0.1°C, April 9, 15.

SPECIFIC CONDUCTANCE: Maximum recorded, 2,960 microsiemens, May 15; minimum recorded, 510 microsiemens, September 11.

PH: Maximum recorded, 8.8 units on many days in May, July, and August; minimum recorded, 7.8 units, September 2, 3.

DISSOLVED OXYGEN: Maximum recorded, 12.8 milligrams per liter, April 9, 15; minimum recorded, 3.0 milligrams per liter, September 10.

EXTREMES FOR PERIOD - MARCH 9-NOVEMBER 2, 2016:

WATER TEMPERATURE: Maximum recorded, 34.2°C, July 21; minimum recorded, -0.1°C, March 26.

SPECIFIC CONDUCTANCE: Maximum recorded, 3,370 microsiemens, July 6; minimum recorded, 583 microsiemens, September 7.

PH: Maximum recorded, 9.1 units, June 6, August 31 and September 1; minimum recorded, 8.1 units, August 9, 10.

DISSOLVED OXYGEN: Maximum recorded, 13.1 milligrams per liter, August 13; minimum recorded, 4.7 milligrams per liter, September 6.

EXTREMES FOR PERIOD OF DAILY RECORD -

WATER TEMPERATURE: Maximum recorded, 33.2°C, July 20, 2016; minimum recorded, 0.1°C, March 20, 2016.

SPECIFIC CONDUCTANCE: Maximum recorded, 3,770 microsiemens, April 30, 2016; minimum recorded, 761 microsiemens, April 6, 2013.

PH: Maximum recorded, 8.7 units, many days; minimum recorded, 7.6 units, May 29, 2013.

DISSOLVED OXYGEN: Maximum recorded, 14.0 milligrams per liter, March 18-20, 2016; minimum recorded, 4.8 milligrams per liter, September 11, 2013.

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NPS 387/167029, February 2020

National Park Service
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