



# Water Quality Monitoring for Devils Tower National Monument

## *2022 Data Report*

Natural Resource Data Series NPS/DETO/NRDS—2024/XXXX





**ON THIS PAGE**

Upstream view of the Belle Fourche River and PVC pipe for sonde from the gage station at Devils Tower National Monument, Wyoming, in May 2022.

**ON THE COVER**

Photograph of Downstream view of gage at Belle Fourche River at Devils Tower National Monument, WY, 2022.  
Photograph courtesy of USGS at Station 06427850.

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# **Water Quality Monitoring for Devils Tower National Monument**

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## Abstract

The Northern Great Plains Inventory and Monitoring Network (NGPN) began monitoring water quality in the Belle Fourche River at Devils Tower National Monument (DETO) in 2013, with the assistance of the U.S. Geological Survey (USGS). This report summarizes the fourth sampling season in 2022 for streamflow, water temperature, dissolved oxygen, specific conductance, and pH. The sampling was conducted during the ice-free season from April 7, 2022 to October 26, 2022. NGPN's collaboration with USGS supported real-time and archived access to this data through the USGS National Water Information System Website, [BELLE FOURCHE RIVER AT DEVILS TOWER, WY - USGS Water Data for the Nation](#), where it remains available to the public.

2022 was a dry year with less than 80% average precipitation. The Belle Fourche River was very low till Keyhole Reservoir started releasing water in late July. The mean stage height of 1.432 ft on the Belle Fourche River was the lowest height yet recorded and a minimum stage height below 1 ft (.92 ft) had not been recorded till 2022 out of four years of data (2013, 2016, 2019, and 2022). There was considerable seasonal variation in all water quality measures, but the values were generally poor compared to previous years (warmer temperatures, lower oxygen levels, and higher conductivity which are commonly associated with low water levels). 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). Slight exceedances for water temperature (.74%) and dissolved oxygen (3.55%) exceedances of water quality standards occurred in 2022. The Belle Fourche River at Devils Tower is currently impaired for fecal coliform which impacts the recreation use of the river. There is a total maximum daily load (TMDL) plan in place to restore water quality.

## **Acknowledgements**

We would like to acknowledge Wyoming-Montana Water Science Center USGS staff including Eric Blajszczak and Jason Swanson for collecting and curating the water quality data.

# Introduction

Devils Tower National Monument (DETO) was established in 1906 as the first National Monument in the United States, with a mission to preserve the Tower and the surrounding 1347 acres (545 ha) of ponderosa pine forests, mixed-grass prairies, and riparian corridor along the Belle Fourche River. Although there are several springs in the Monument, the Belle Fourche River is the major hydrologic feature of the park (NPS 1997). The Belle Fourche River is about 290 miles (470 km) long from the headwaters in northeastern Wyoming to its confluence with the Cheyenne River approximately 50 miles ENE of Rapid City, South Dakota (Figure 1). Northeastern Wyoming is a dry region; on average it receives 17 inches of precipitation annually, with two-thirds of that precipitation occurring as rain in the spring and summer.

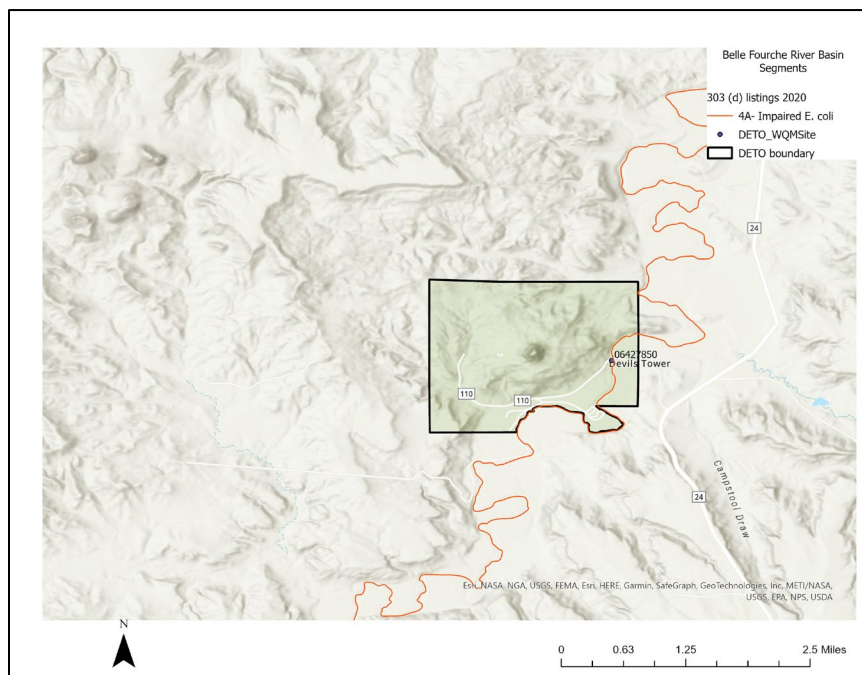


**Figure 1.** Map of the Devils Tower National Monument and the Belle Fourche River in Wyoming. The river reach that runs through the monument, highlighted in red, is listed as impaired under 303(d) criteria for fecal coliform bacteria.

Approximately 2 miles (3.6 km) of the Belle Fourche River runs through DETO as the river flows northeast toward South Dakota. In this area, river flow tends to peak between March and June, while annual low flows occur in November and December. River flow seasonality has been limited since 1952 by the construction of the Keyhole Reservoir and dam upstream of DETO. This reduced the floods that cottonwood seedlings relied on for germination and establishment (Martin 1995). The river has become deeply incised, creating areas along the river where the water table is now 1.7–2.2 m deep and typical riparian vegetation, such as willows, are largely absent, having been replaced by grassland (Anderson 2013).

Primary land uses in the region include livestock grazing, hay production, mineral extraction, and oil and gas production (WYDEQ 2020). The Belle Fourche River is designated as a Class 2AB warm water fishery, defined as a water known to support game fish populations or spawning and nursery areas at least seasonally and where a game fishery and drinking water use is attainable (WYDEQ 2018b). Several stretches of the river are listed as impaired waterways under section 303(d) of the Clean Water Act, including the 60.7-mile stretch running through DETO, from Arch Creek to Sourdough Creek, AUID= WYBF101202010904\_00. This reach is impaired for fecal coliform bacteria (WYDEQ 2020). The Belle Fourche River reach running through Devils Tower is in the 17a Black Hills Foothills Level IV Ecoregion (Chapman et al 2003). It is best described as a ponderosa pine woodland and grassland savanna with 15–20 inches of precipitation annually. Livestock grazing, ranching, recreation, and wildlife habitat are described as the primary land uses with some gypsum and copper mining in the area (Chapman 2003).

Water quality monitoring at DETO in the 1970s found fecal coliform bacteria levels above state thresholds on several occasions in 1974 and 1975 (NPS 1997). Bacteria is a widespread problem in the Belle Fourche River. All three of the assessed Wyoming reaches are impaired for bacteria, and five out of five reaches of the Belle Fourche in South Dakota are nonsupporting for bacteria as well (SD DANR 2020). Use determinations have only been completed on 2% of the surface water in the Belle Fourche Watershed in Wyoming (WY DEQ 2020). Nonpoint source pollution is the determined cause of bacterial impairments (Tetra Tech Inc 2013). Livestock, possibly failing septic systems, and other wildlife are likely suspects for contributing to high bacteria loads (Tetra Tech Inc 2013). The human population is very sparse around Devils Tower with only an estimated 300 households living along the reach and a total population of 7,181 in Crook’s County (2020 census). The 2017 NASS livestock census indicates Crook County supports 67,640 cattle and calves and 12,214 sheep and lambs. Bacteria data collection in the Belle Fourche River is sparse as well, and further sampling has not been done after the total maximum daily load (TMDL) was published in 2013. The river was sampled above and below the town of Hulett, WY and found no significant increase below the town. As with many bacterial impairments, concentrations increase after high flows (TetraTech 2013), and loads should be reduced at these high flows to meet the TMDL. Grazing land management, riparian buffers, and alternative watering systems are recommended to reduce bacteria loads. For more details and current impairment information visit the [Wyoming Department of Environmental Quality website](#).

The Northern Great Plains Inventory & Monitoring Network (NGPN) began monitoring water quality at DETO in 2013 to better understand current conditions and changes over time in the Belle Fourche River (Ashton et al. 2020). The monitoring is conducted at the gaging station at Devils Tower National Monument, WY (Monitoring Location 06427850; 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 repeats water quality monitoring at DETO every three years, (Wilson et al. 2014), conducting in-depth analysis of status and trends after three to five cycles of sampling. This report summarizes data from the fourth season of water quality sampling in 2022.

NGPN's core water quality parameters include streamflow, dissolved oxygen (DO), pH, specific conductivity, and water temperature (Table 1). These parameters were 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](https://nwis.waterdata.usgs.gov/).



**Figure 2.** Map of Devils Tower National Monument and water quality monitoring location (blue triangle) and nearby weather stations (red flags). Climate data in this report is taken from the DEVILS TWR 2 weather station.

**Table 1.** Water quality parameters measured as part of the Northern Great Plains Inventory & Monitoring Water Quality Program and associated state standards (WYDEQ 2018a). These standards are not enforceable in periods of low flow, as defined by the minimum seven consecutive day flow which has the probability of occurring once in ten years (WYDEQ 2018a).

| Water Quality Parameter      | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | WY state standards applicable to warm water fisheries designations                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Water temperature (°C)       | Water temperature is affected by solar radiation, air temperature, rainfall, flow dynamics, physiography of the waterbody, stream shading, land use/cover, and land development in the watershed. Water temperature monitoring indicates response to daily and annual climatic variations and may track short-term drought or long-term climate changes. Water temperature can indicate changes in water use, source, and flow dynamics. Aquatic organisms are dependent on specific temperature ranges for their optimum health and survival. | <p>Pollution attributable to the activities of man shall not change ambient water temperatures to levels which result in harmful acute or chronic effects to aquatic life, or which would not fully support existing and designated uses.</p> <p>When ambient temperatures are above 15.6°C, pollution attributable to the activities of man shall not result in an increase of more than 2.2°C.</p> <p>The maximum allowable stream temperature will be the maximum natural daily stream temperature plus the allowable change, provided that this temperature is not lethal to existing fish life and under no circumstance shall pollution attributable to the activities of man result in a temperature that exceeds 30°C.</p> |
| Dissolved Oxygen (mg/L)      | The DO level, a measure of the amount of oxygen in the water column, is considered an important indicator of a waterbody's ability to support aquatic life. The DO in rivers and streams typically declines as temperature increases and as flow decreases; DO also responds to photosynthesis, resulting in natural variation during the day and additional natural variation through the season. The DO in water can vary over extended periods of time due to changes in the landscape or climate.                                          | <p>Minimum criteria include:</p> <ul style="list-style-type: none"> <li>• 30-day mean of 5.5 mg/L</li> <li>• 7-day mean of 6.0 mg/L</li> <li>• 7-day mean minimum of 4.0 mg/L</li> <li>• 1-day minimum of 5.0 mg/L</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| Specific Conductance (µS/cm) | Specific conductance, a measured concentration of the water's ability to conduct electricity, typically is proportional to the dissolved major ions in the water such as calcium, magnesium, sodium, and sulfate. A change in specific conductance indicates a change in the concentration(s) of major ions. Small changes in specific conductance are common through the day and through the seasons.                                                                                                                                         | No criteria                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |

**Table 1 (continued).** Water quality parameters measured as part of the Northern Great Plains Inventory & Monitoring Water Quality Program and associated state standards (WYDEQ 2018a). These standards are not enforceable in periods of low flow, as defined by the minimum seven consecutive day flow which has the probability of occurring once in ten years (WYDEQ 2018a).

| <b>Water Quality Parameter</b> | <b>Description</b>                                                                                                                                                                                                                                                       | <b>WY state standards applicable to warm water fisheries designations</b>                                                                                                                                                                                                                                                                                                                                                                                     |
|--------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| pH                             | The pH is a measure of the hydrogen ion concentration in a solution. The pH in surface waters typically ranges from 6.5 to 8.5. pH may be influenced by watershed vegetation, hydrology, geology, and soils. Different organisms flourish within different ranges of pH. | <p>Pollution attributable to the activities of man shall not be present in amounts which will cause the pH to be less than 6.5 or greater than 9.0 standard units.</p> <p>Pollution attributable to the activities of man shall not change the pH to levels which result in harmful acute or chronic effects to aquatic life, directly or in conjunction with other chemical constituents, or which would not fully support existing and designated uses.</p> |

## 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 06427850) inside the park at 3840 ft. elevation. Water quality and stage height are measured every 15 minutes throughout the ice-free season. Monitoring at DETO began in 2013 and was repeated in 2016, 2019, 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 2022, NGPN partnered with the USGS Wyoming-Montana Water Science Center to have USGS staff collect water quality and streamflow data at DETO. The USGS deployed a continuous, multi-parameter sonde at the gage on April 7, 2022 (Figure 3) and visited the gaging station every 3–4 weeks for equipment maintenance (Table 2). This instrument recorded dissolved oxygen, pH, specific conductivity, and water temperature every 15 minutes, while the gage simultaneously measured stream stage (or gage height).



**Figure 3.** A researcher deploys a sonde device to measure water quality on the Belle Fourche River at Devils Tower, WY. The United States Geological Survey Belle Fourche River gaging station (06427850) is set up for real-time data transmission via satellite. Photographs courtesy of NPS.

**Table 2.** Field journal for 2022 Water Quality Sampling at Devils Tower National Monument.

| Date      | Notes                                                                                                             |
|-----------|-------------------------------------------------------------------------------------------------------------------|
| 7-Apr-22  | Instrument installed. Levels ran.                                                                                 |
| 5-May-22  | Heavy sediment in sonde on arrival. Cleaning and calibration. Cross-section.                                      |
| 7-Jun-22  | Minor aquatics on monitor sonde. Cleaning and calibration. Cross-section.                                         |
| 13-Jul-22 | Cleaning and calibration. Cross-section.                                                                          |
| 2-Aug-22  | Heavy debris on sonde pipe prior to cleaning. Cleaning and calibration. Cross-section.                            |
| 14-Sep-22 | Heavy moss, algae, and silt on pipe prior to cleaning. Cleaning and calibration. Swapped pH probe. Cross-section. |
| 26-Oct-22 | WQ Monitor pulled for season. Cross-section.                                                                      |

Satellite telemetry transmitted the water data to the Water Science Center in near real-time (<https://waterdata.usgs.gov/monitoring-location/06427850/>). 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 with 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 (Table 2). Calibration included pre- and post-calibration checks to quantify fouling errors and equipment drift—data critical to the correction and grading of the final data. On October 26, 2022, the USGS removed the multi-parameter sonde from the Belle Fourche 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 January of 2022 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). Discharge data were not available for this site (only stage height), so a nearby stream gage on the Belle Fourche River at the Wyoming and South Dakota border was used as a proxy (USGS ID number 06428500).

Climate data were downloaded from the Devils Tower 2 (482466) National Weather Service Cooperator Observer Program station. The data were accessed and graphed using the web-based tool [Climate Analyzer](#).

## Results

The water quality monitoring season (ice-free) on the Belle Fourche River at DETO lasted from April 7, 2022 to October 26, 2022. The discharge of the Belle Fourche River peaked in late April, earlier than usual, and was generally low (Figure 4). The maximum recorded gage height was on April 27, 2022 at 2.77 ft and the minimum recorded gage height was recorded on July 21-22, 2022 at .92 ft (Appendix A), a record low for this site. Peak stage height in 2022 was less than three feet, as opposed to over 7 feet in 2019. Peak discharge at station 06428500 was less than 400 cubic ft per second, whereas 2019 had much higher flows, close to 2,500 cfs. 2022 was drier than average when compared to 1981–2010 (precipitation was ~80% of average) though exact percentages could not be calculated due to missing data.

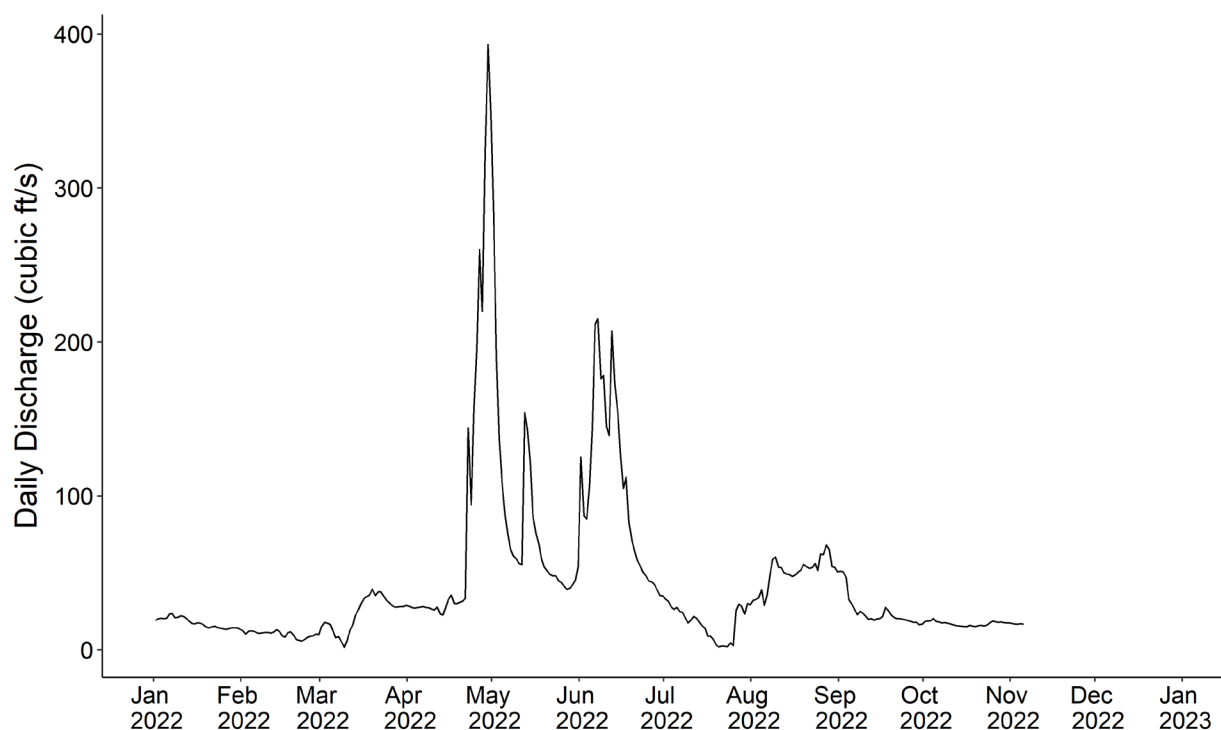


**Figure 4.** Daily mean discharge (black line) in 2022 on the Belle Fourche River at the Wyoming – South Dakota border, USGS Gaging Station 06428500.

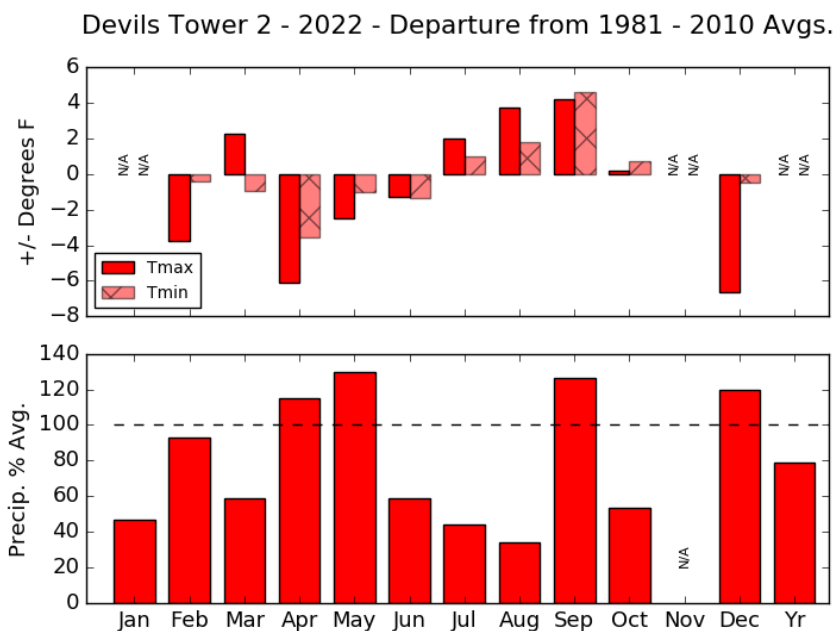
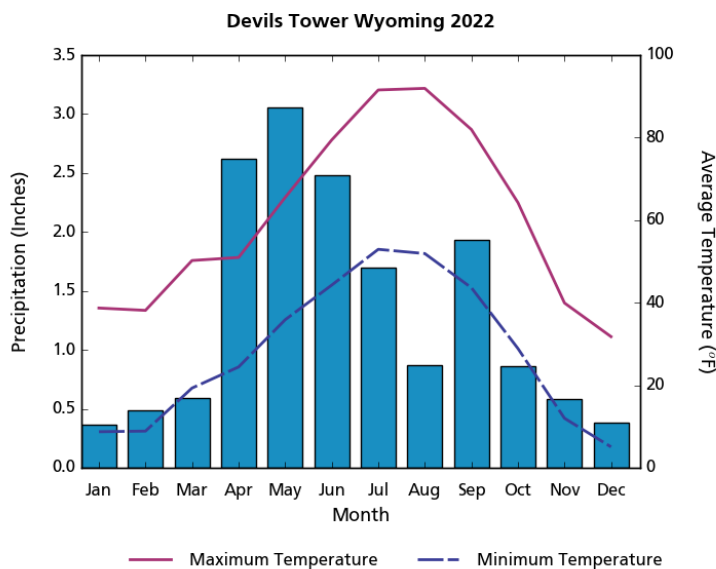


**Figure 5.** The top panel shows total monthly precipitation (light blue bars), average monthly minimum temperature (dashed blue line), and average monthly maximum temperature (solid red line) for 2022 in Devils Tower National Monument. The bottom panel shows monthly departures from 1981–2010 average temperature and precipitation for 2022 in Devils Tower National Monument. Climate data are from Devils Tower 2 Station (482466). The data were accessed and graphed using the web-based tool Climate Analyzer.

During the ice-free season at DETO, we collected over 18,000 water quality measurements in the Belle Fourche River (Table 3). We measured a mean water temperature of 17.4°C, dissolved oxygen concentrations of 8.49 mg/L, specific conductance of 1651  $\mu\text{S}/\text{cm}$ , and pH of 8.09 (Table 3). For

comparison, mean water temperature was only 14.64°C in 2019. There was, however, variation across months in all parameters (Table 4). Mean water temperature in April was 7.34°C and increased to a mean of close to 24.53°C in July before declining back to 10.21°C in October (Table 4, Figure 6). Maximum water temperature did exceed the Wyoming water quality standard of 30°C (Table 1) nearly 5% of the time in July. These high water temperatures were due not only to high air temperature, but more importantly, to very low water levels (Matthews 1988).

**Table 3.** Summary of descriptive statistics for water temperature, dissolved oxygen, specific conductance, and pH measured for the ice-free sampling period on the Belle Fourche River at Devils Tower National Monument from April 7, 2022 through October 26, 2022. Percent exceedance is the proportion of samples that exceed the respective state regulatory threshold described in Table 1 (water temperature max. limit is 30.0°C; dissolved oxygen  $\geq 5.0$  mg/L and pH range is <6.5 or >9.0).

| Descriptive Statistic                    | Water Temperature (°C) | Dissolved Oxygen (mg/L) | Specific Conductance ( $\mu$ S/cm) | pH        |
|------------------------------------------|------------------------|-------------------------|------------------------------------|-----------|
| Mean                                     | 17.4                   | 8.49                    | 1651.95                            | 8.09      |
| Standard Deviation                       | 6.56                   | 2.11                    | 274.08                             | 0.24      |
| Median                                   | 18.8                   | 8.4                     | 1710                               | 8.1       |
| Minimum                                  | -0.1                   | 3.7                     | 719                                | 7.3       |
| Maximum                                  | 32.2                   | 13.1                    | 2220                               | 8.6       |
| Number of Points                         | 19363                  | 18006                   | 18661                              | 19286     |
| Standard                                 | <30°C                  | > 5 mg/L                | NA                                 | 6.5–9.0   |
| Number of Points below or above standard | 143 (above)            | 639 (below)             | NA                                 | 0 (above) |
|                                          |                        |                         |                                    | 0 (below) |
| % Exceedance                             | 1%                     | 4%                      | NA                                 | 0%        |

**Table 4.** Monthly summary of descriptive statistics and percent exceedances for core water quality parameters for the ice-free sampling period at Devils Tower National Monument on the Belle Fourche River from April 7, 2022 through October 26, 2022. Percent exceedance is the proportion of samples that exceed the respective state regulatory threshold described in Table 1 (water temperature max. limit is 30.0°C; dissolved oxygen  $\geq 5.0$  mg/L and pH range is <6.5 or >9.0).

| Dates                    | Descriptive Statistic  | Water Temperature (°C) | Dissolved Oxygen (mg/L) | Specific Conductivity ( $\mu$ S/cm) | pH   |
|--------------------------|------------------------|------------------------|-------------------------|-------------------------------------|------|
| April 7 – April 30, 2022 | Number of measurements | 2253                   | 1893                    | 2171                                | 2252 |
|                          | Mean                   | 7.34                   | 10.74                   | 1801.35                             | 8.25 |
|                          | Standard Deviation     | 3.65                   | 1.28                    | 370.82                              | 0.2  |
|                          | Median                 | 8.1                    | 11                      | 1990                                | 8.3  |

|              |                        |       |       |         |      |
|--------------|------------------------|-------|-------|---------|------|
|              | Minimum                | -0.1  | 8     | 780     | 7.8  |
|              | Maximum                | 15.4  | 13    | 2080    | 8.5  |
|              | % Exceedance           | 0     | 0     | NA      | 0    |
| May, 2022    | Number of measurements | 2972  | 2544  | 2945    | 2972 |
|              | Mean                   | 14.97 | 8.93  | 1599.67 | 8.15 |
|              | Standard Deviation     | 3.8   | 1.57  | 172.04  | 0.17 |
|              | Median                 | 15    | 8.8   | 1660    | 8.2  |
|              | Minimum                | 7.4   | 5.9   | 1040    | 7.7  |
|              | Maximum                | 24    | 12.1  | 1790    | 8.6  |
|              | % Exceedance           | 0     | 0     | NA      | 0    |
| June, 2022   | Number of measurements | 2876  | 2876  | 2876    | 2876 |
|              | Mean                   | 20.82 | 7.71  | 1205.79 | 7.94 |
|              | Standard Deviation     | 3.22  | 1.76  | 231.61  | 0.28 |
|              | Median                 | 20.9  | 7.2   | 1260    | 8    |
|              | Minimum                | 10.8  | 5     | 719     | 7.4  |
|              | Maximum                | 27.9  | 12.3  | 1750    | 8.5  |
|              | % Exceedance           | 0     | 0     | NA      | 0    |
| July, 2022   | Number of measurements | 2975  | 2606  | 2759    | 2975 |
|              | Mean                   | 24.53 | 7.2   | 1764.74 | 7.95 |
|              | Standard Deviation     | 2.87  | 2.36  | 125.72  | 0.32 |
|              | Median                 | 24.2  | 6.7   | 1740    | 8    |
|              | Minimum                | 17.6  | 3.7   | 1490    | 7.3  |
|              | Maximum                | 32.2  | 11.8  | 2220    | 8.4  |
|              | % Exceedance           | 4.81  | 20.57 | NA      | 0    |
| August, 2022 | Number of measurements | 2973  | 2832  | 2926    | 2972 |
|              | Mean                   | 22.34 | 7.67  | 1649.16 | 8.18 |
|              | Standard Deviation     | 2.1   | 1.15  | 22.41   | 0.11 |
|              | Median                 | 22.2  | 7.4   | 1640    | 8.2  |
|              | Minimum                | 17.8  | 5.7   | 1620    | 8    |
|              | Maximum                | 27.5  | 10.7  | 1740    | 8.4  |

|                       |                           |       |      |         |      |
|-----------------------|---------------------------|-------|------|---------|------|
|                       | % Exceedance              | 0     | 0    | NA      | 0    |
| September,<br>2022    | Number of<br>measurements | 2874  | 2815 | 2831    | 2807 |
|                       | Mean                      | 18    | 8.18 | 1771.2  | 8.13 |
|                       | Standard Deviation        | 3.31  | 2.15 | 52.23   | 0.17 |
|                       | Median                    | 18.1  | 7.7  | 1770    | 8.1  |
|                       | Minimum                   | 10.9  | 4.2  | 1650    | 7.7  |
|                       | Maximum                   | 26.2  | 12.8 | 1880    | 8.5  |
|                       | % Exceedance              | 0     | 3.66 | NA      | 0    |
| October 1-26,<br>2022 | Number of<br>measurements | 2440  | 2440 | 2153    | 2432 |
|                       | Mean                      | 10.21 | 9.9  | 1871.23 | 8.09 |
|                       | Standard Deviation        | 3.61  | 1.69 | 24.49   | 0.17 |
|                       | Median                    | 9.9   | 9.6  | 1870    | 8.1  |
|                       | Minimum                   | 2.5   | 6.2  | 1840    | 7.7  |
|                       | Maximum                   | 18.6  | 13.1 | 1950    | 8.4  |
|                       | % Exceedance              | 0     | 0    | NA      | 0    |

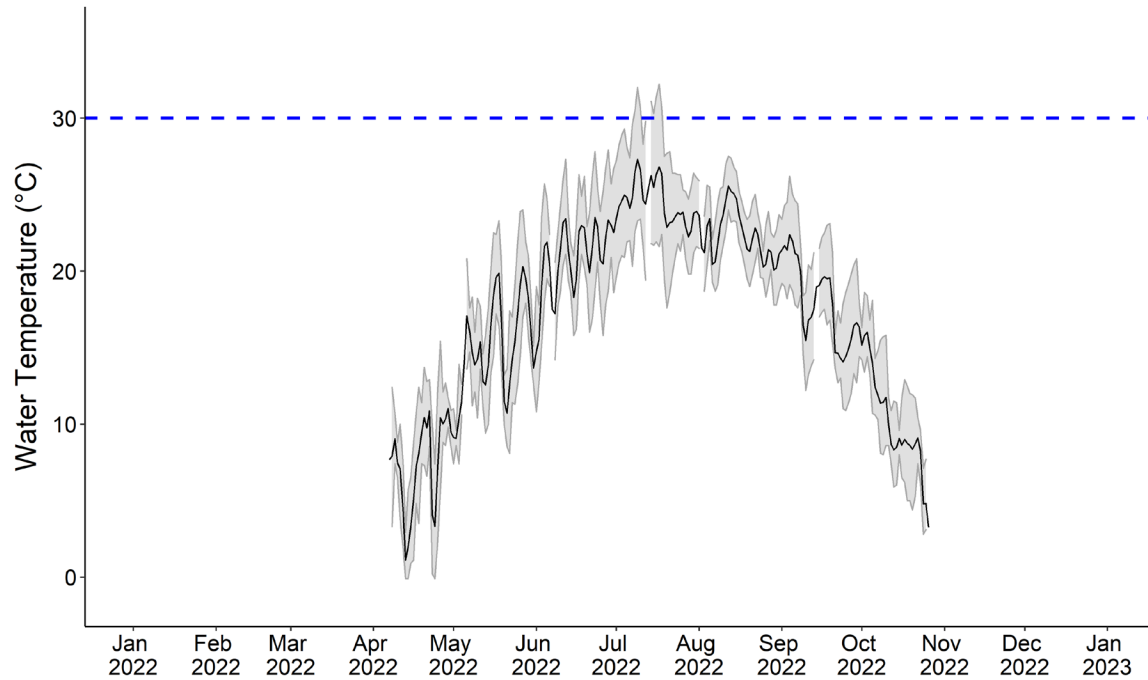


**Figure 6.** Daily mean water temperature (black line) collected on the Belle Fourche River at Devils Tower National Monument in 2022. The sonde was in the water from April 7, 2022 till October 26, 2022. The gray ribbon shows the daily maximum and minimum water temperature for the same period. The dashed blue line indicates one of the Wyoming 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.** July brought very low water levels (a), high algal growth(b), and high stream temperatures to the Belle Fourche River at DETO. These coincided with low dissolved oxygen levels. Low oxygen and high temperatures are stressful for aquatic life(c, Matthews 1988).

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 10 mg/ L in April but only 7.2 mg/L in July. Over 20% of the measurements in July fell below state standards for dissolved oxygen, falling to a minimum of 3.7 mg/L. These low measurements coincided with high stream temperatures, high algal growth, and very low water levels.

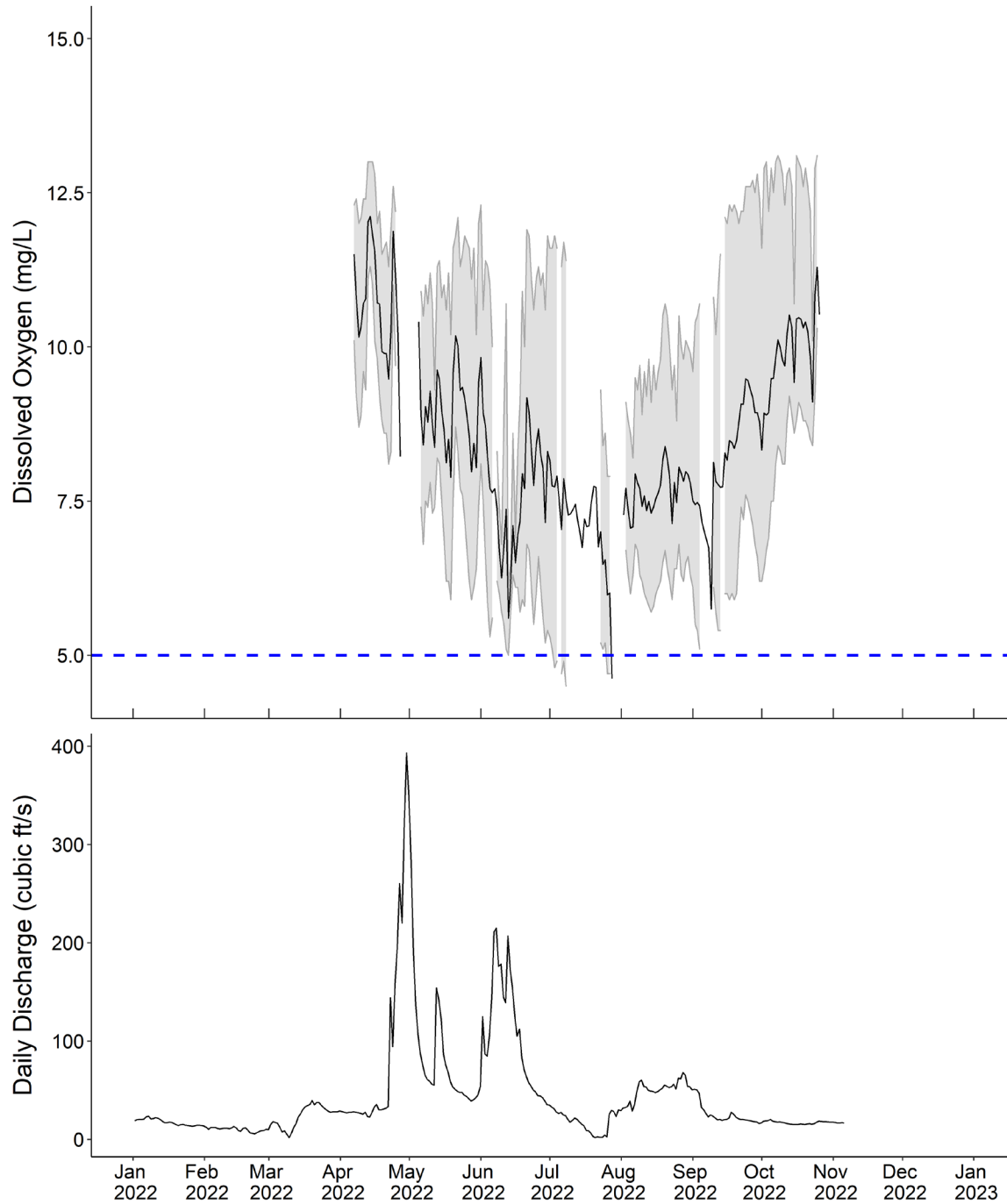


**Figure 8.** Daily mean dissolved oxygen concentrations (top) of the Belle Fourche River at Devils Tower National Monument in 2022 and daily discharge (bottom) of the Belle Fourche River at the Wyoming and South Dakota border. The gray ribbon shows the daily maximum and minimum dissolved oxygen for the same period. The dashed blue line indicates one of the Wyoming 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.

Specific conductance of the Belle Fourche River was highly variable throughout the year, ranging from 719 to 2200  $\mu\text{S}/\text{cm}$  (Table 3, Figure 9), but showed a less predictable seasonal pattern than temperature or dissolved oxygen concentrations. 2220 was on the high end of conductivity and can be associated with periods of drought and lack of flushing. The pH of the Belle Fourche River ranged between 7.3 and 8.6 (Figure 10), and it was never outside the range of the Wyoming state standards of 6.5–9.

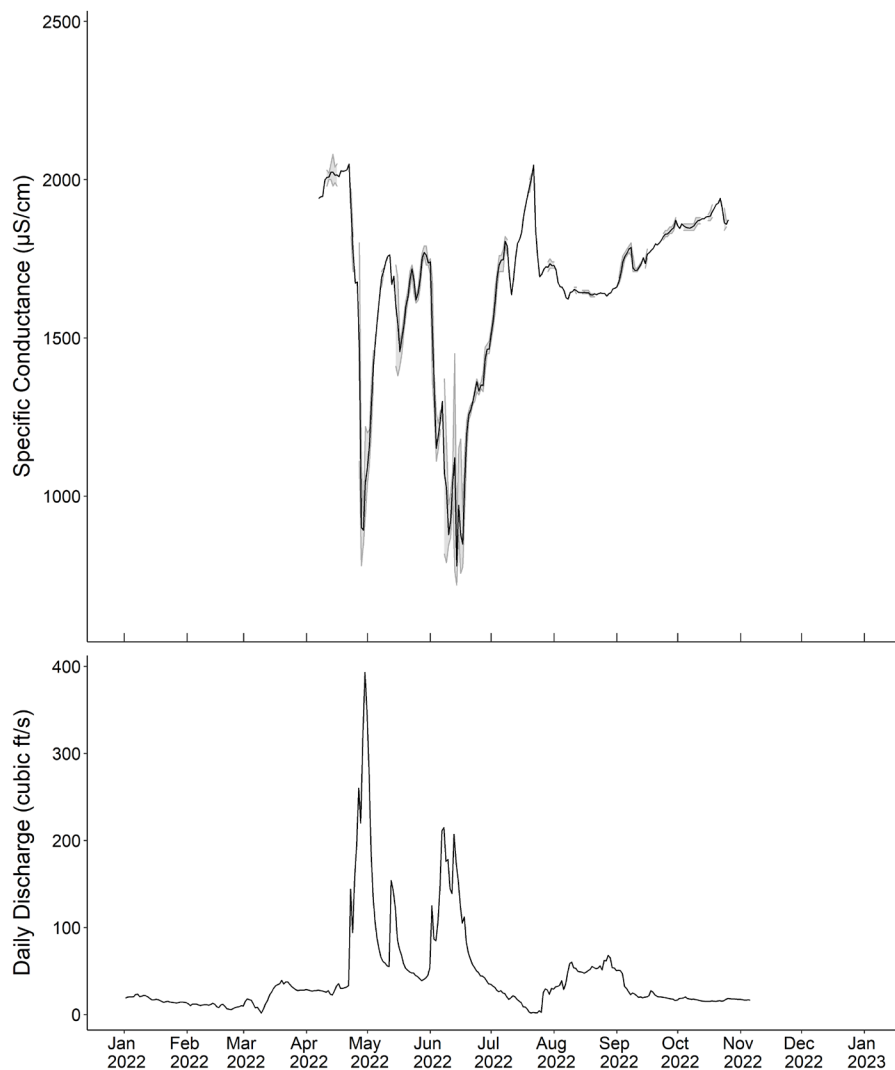


**Figure 9.** Daily mean specific conductance (top) of the Belle Fourche River at Devils Tower National Monument in 2022 and daily discharge (bottom) of the Belle Fourche River at the Wyoming and South Dakota border. The gray ribbon shows the daily maximum and minimum specific conductivity for the same period. The periods where the instrument did not collect data are indicated by gaps in the record.

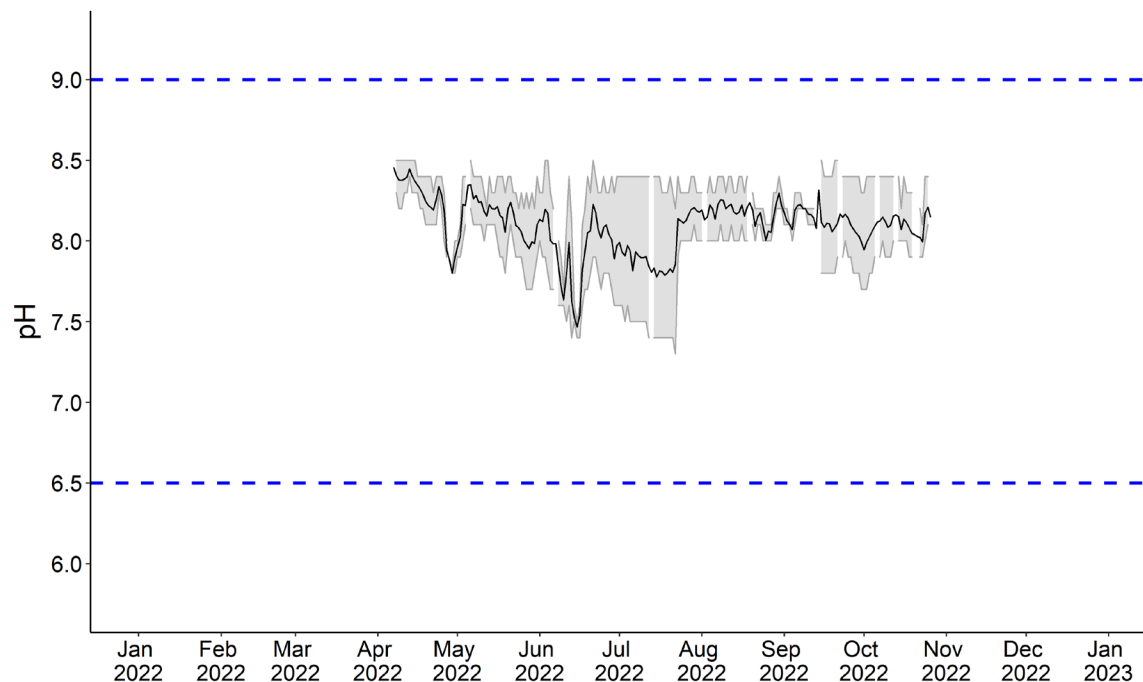


**Figure 10.** Daily mean pH (black line) of the Belle Fourche River at Devils Tower National Monument in 2022. Measurements were taken from April 7, 2022 through October 26, 2022. The gray ribbon shows the daily maximum and minimum pH for the same period. The dashed blue lines indicate the Wyoming state 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 data collected during the 2022 water quality monitoring season at Devils Tower National Monument. 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 [BELLE FOURCHE RIVER AT DEVILS TOWER, WY - USGS Water Data for the Nation](#).

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