PLYMOUTH CREEK
2022–2023 Stream Monitoring and 2022 Biotic Index Evaluation

Bassett Creek Watershed Management Commission

Plymouth Creek monitoring

The Bassett Creek Watershed Management Commission (BCWMC) monitored Plymouth Creek for water depth, flow, temperature, specific conductance, dissolved oxygen, and stream water quality during 2022 and 2023. In 2022, the BCWMC monitored the stream's habitat and macroinvertebrates. The macroinvertebrate data were used to complete a biotic index evaluation of the stream. This report presents the results of these monitoring efforts.

At a glance: 2022 and 2023 monitoring results

Two sites along Plymouth Creek, IP1 and IP2, were monitored in 2022–2023. Both sites are near an industrial building at 12940 Teakwood Lane North in Plymouth. The monitoring of IP2 was part of an ongoing program by the City of Plymouth to evaluate nutrients and chlorides from upstream portions of Plymouth Creek flowing into Medicine Lake. IP1, downstream from IP2, was added to the 2022–2023 monitoring program primarily to evaluate flow and chlorides added to the stream from a subwatershed west of Highway 55.

This report includes the following recent Plymouth Creek monitoring efforts:

- In 2022 and 2023, the City of Plymouth contracted with Three Rivers Park District to collect flow data, continuous temperature and specific conductance data, and water quality samples from Plymouth Creek for analyses by the Three Rivers Park District laboratory.
- In 2022 and 2023, the BCWMC collected quarterly water quality samples from Plymouth Creek for analyses by the Metropolitan Council Environmental Services laboratory.
- In August of 2022 and August of 2023, BCWMC collected continuous dissolved oxygen and temperature data from Plymouth Creek.
- In September of 2022, the BCWMC collected habitat and macroinvertebrate data from Plymouth Creek.

The purpose of the stream monitoring program was to evaluate flow and water quality, detect changes over time, evaluate whether the Minnesota Pollution Control Agency (MPCA) water quality and biological standards were met, and identify stressors to the biological community.

Results of the Plymouth Creek monitoring program show that MPCA standards were met for temperature, pH, chlorophyll *a*, metals (total cadmium, chromium, copper, nickel, lead, zinc), and dissolved oxygen flux. Total phosphorus did not meet its MPCA standard. However, the MPCA evaluates total phosphorus in combination with chlorophyll *a* and dissolved oxygen flux (the MPCA's river eutrophication standard [RES]) to determine whether the stream is impaired due to eutrophication. The high total phosphorus concentrations in Plymouth Creek did not result in high chlorophyll *a* and dissolved oxygen flux in Plymouth Creek because both met their respective MPCA standards. Therefore, the stream met the MPCA's RES and is not considered impaired.

About Plymouth Creek

Stream length (miles)	6 miles
Size of drainage area (acres)	4,329
Location of stream origin	Plymouth
Downstream receiving waterbody	Medicine Lake
MPCA impairments	Chloride, *Escherichia coli*

Escherichia coli (E. coli) bacteria met the MPCA standard for individual values but did not meet the standard for monthly aggregated geometric means. However, the stream could not be assessed for impairment using geometric means because an insufficient number of samples were collected during the 2022 through 2023 monitoring period.

The stream failed to meet MPCA standards for dissolved oxygen, total suspended solids, and chlorides.

Between 1980 and 2022, the BCWMC collected benthic macroinvertebrates (bottom-dwelling organisms) from Plymouth Creek on 11 occasions to evaluate water quality and to detect changes over time. The 2022 monitoring program evaluated habitat and macroinvertebrates.

Changes between 2015 and 2022 habitat evaluations include increases in the depth of fine sediment, the length of bank erosion, and the amount of algae. Dry climatic conditions in 2022 resulted in decreases in flows and water depth.

The MPCA developed and added the Macroinvertebrate Index of Biotic Integrity (M-IBI) to Minnesota's water quality standards to help identify biologically impaired rivers and streams. Macroinvertebrate data collected by BCWMC from 1991 through 2022 and by the MPCA in 2010 and 2020 were evaluated using the M-IBI. All M-IBI scores were compared with the MPCA Macroinvertebrate Class 5 (Southern Streams) standard, a minimum score of 37. None of the M-IBI scores met the MPCA standard. M-IBI scores

from BCWMC data ranged from a low of 13 to a high of 32 and the 2022 score was 14. The MPCA scores ranged from 7.7 in 2020 to 24.9 in 2010. Both MPCA scores were below the MPCA standard, resulting in Plymouth Creek being added to Minnesota's impaired waters list for aquatic life-benthic macroinvertebtatess bioassessments in 2024.

The MPCA completed a Stressor Identification (SID) for Plymouth Creek in 2024 to determine stressors causing biological impairment in the stream. The most common stressor found was altered hydrology and connectivity followed by eutrophication due to excess total phosphorus, inadequate dissolved oxygen, excess chloride, and excess total suspended solids. The 2022–2023 Plymouth Creek data were consistent with MPCA findings, with inadequate dissolved oxygen, excess chloride, excess total suspended solids, and excess total phosphorus. The 2022–2023 Plymouth Creek data also identified inadequate flow as a stressor to the biological community. Dry climatic conditions in 2022 and 2023 resulted in no flow at:

- Plymouth Creek monitoring location Industrial Park 1 (IP1) during 12 percent of the monitored period in 2022 and 13 percent of the monitored period in 2023.
- Plymouth Creek monitoring location Industrial Park 2 (IP2) during 40 percent of the monitored period in 2022 and 33 percent of the monitored period in 2023.

Monitoring locations IP1 and IP2 are shown in Figure 1.

Recommendations

- Evaluate the causes of excess total suspended solids and total phosphorus in the stream and identify measures to improve water quality.
- Evaluate the stream corridor for erosion and identify and implement management measures to repair the erosion.
- Work with cities, businesses, the Minnesota Department of Transportation, and Hennepin County to improve winter maintenance practices and reduce the chloride load conveyed to Plymouth Creek from streets and parking lots in its watershed.
- Continue monitoring of stream habitat, flow, water quality, and macroinvertebrates to evaluate whether the stream meets MPCA water quality and biological standards and identify changes over time, including changes to the stressors of the macroinvertebrate community.

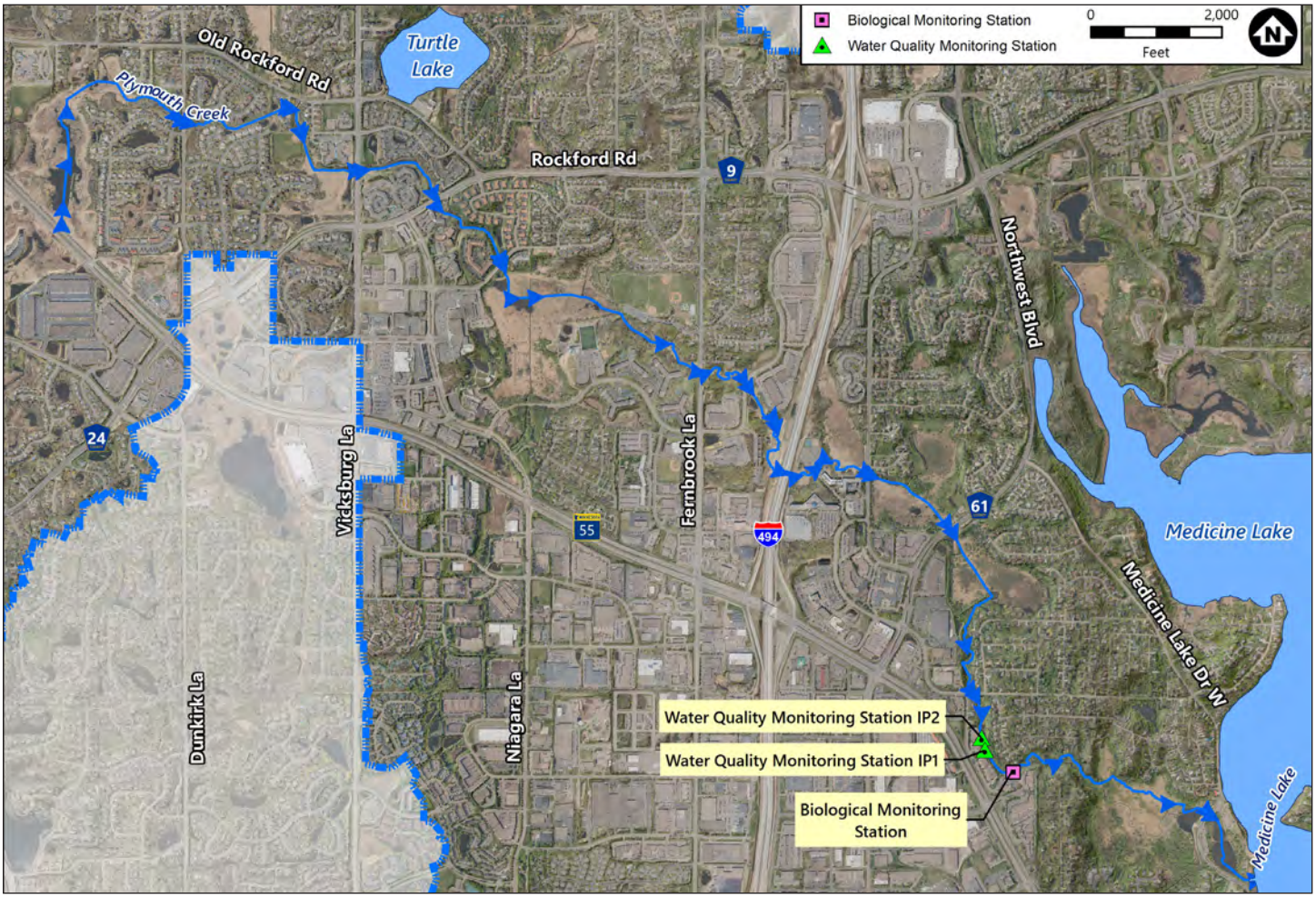

Figure 1 Plymouth Creek water quality and biological monitoring locations

2022–2023 stream monitoring program

Plymouth Creek was monitored from 2022 through 2023 at two locations, IP1 and IP2, shown in Figure 1. IP2 is monitored by the City of Plymouth as part of an ongoing monitoring program. IP1 was added primarily to evaluate flow and chlorides coming from a subwatershed west of Highway 55.

Monitoring completed by Three Rivers Park District on behalf of the City of Plymouth included the following:

- Water depth, flow, and temperature were measured continuously at IP1 from April 12, 2022, through October 6, 2022, and from April 6, 2023, through October 23, 2023.
- Specific conductance was measured continuously at IP1 from September 22, 2023, through October 31, 2023.
- Water depth, flow, temperature, and specific conductance were measured continuously at IP2 from March 9, 2022, through October 31, 2022, and from April 6, 2023, through October 22, 2023.
- Temperature, dissolved oxygen, pH, and specific conductance were instantaneously measured at IP1 on 11 occasions from May through September 2022 and on 12 occasions from May through September 2023.
- Temperature, dissolved oxygen, pH, and specific conductance were instantaneously measured at IP2 on 14 occasions from April through September 2022 and on 16 occasions from April through October 2023.
- Water quality samples were collected from IP1 with an automatic sampler on 12 occasions from May through August 2022 and on 12 occasions from June through October 2023 to monitor storm events. Water quality samples were manually collected on four occasions from April through July 2023 to monitor baseflow conditions.
- Water quality samples were collected from IP2 with an automatic sampler on seven occasions from May through August 2022 and 10 occasions from May through October 2023 to monitor storm events. Water samples were collected manually on eight occasions from April through August 2022 and on 10 occasions from April through October 2023 to monitor baseflow conditions.

Monitoring completed by the BCWMC included the following:

- Dissolved oxygen and temperature were continuously measured at IP2 from August 12, 2022, through August 18, 2022, and August 11, 2023, through August 18, 2023.
- Water quality samples were manually collected from IP2 on three occasions in 2022 (June, September, and December) and on three occasions in 2023 (January, May, and September).

Results of 2022–2023 stream monitoring program

Water depth and flow

Water depth and flow were measured at 15-minute intervals throughout the monitoring period at IP1 and IP2 (Figure 1). The results from IP1 are shown in Table 1, Figure 2, and Figure 3. The results from IP2 are shown in Table 2, Figure 4, and Figure 5.

Dry climatic conditions during 2022 and 2023 resulted in no flow at:

- IP1 during 12 percent of the monitored period in 2022 and 13 percent of the monitored period in 2023 (Table 1 and Figure 3).
- IP2 during 40 percent of the monitored period in 2022 and 33 percent of the monitored period in 2023 (Table 2 and Figure 5).

Table 1 2022–2023 water depth and flow at Plymouth Creek Station IP1

Parameter	2022			2023		
	Low	High	Average	Low	High	Average
Average daily water depth (feet)	**0.06** on 9/18–9/19, 9/21–9/22, and 10/2–10/3	**0.27** on 4/30	**0.12**	**0.11** on 9/14	**0.39** on 4/20	**0.17**
Average daily flow (cubic feet per second)	**0.00** on 4/12, 7/25, 8/4–8/5, 9/4–9/6, 9/11–9/12, 9/18–9/19, and 9/26–10/6	**2.2** on 4/30	**0.3**	**0.0** on 5/29, 7/17–7/18, 7/31–8/1, 8/5, 8/8, 8/18, 8/20–8/22, 8/27–8/28, 9/7–9/8, 9/16–9/22, 9/28, 10/2, 10/19, and 10/21–10/22	**6.2** on 4/20	**0.5**

Table 2 2022–2023 water depth and flow at Plymouth Creek Station IP2

Parameter	2022			2023		
	Low	High	Average	Low	High	Average
Average daily water depth (feet)	**0.00** on 6/19–6/20, 7/2–7/3, 7/10–7/11, 7/17–7/22, 7/25, 7/28–8/5, 9/6, 9/9, 9/11–9/16, and 9/18–10/31	**0.80** on 5/1	**0.12**	**0.00** on 6/5–6/17, 6/20–6/23, 6/30, 7/1–7/3, 7/5–7/13, 7/15–7/19, 7/21–7/25, 8/29–9/11, 9/13–9/22	**1.14** on 10/14	**0.20**
Average daily flow (cubic feet per second)	**0.00** on 6/18–6/20, 6/27, 6/29, 7/1–7/3, 7/9–7/11, 7/17–7/22, 7/25, 7/28–8/5, and 9/3–10/31	**32.8** on 5/1	**2.9**	**0.0** on 6/4–6/17, 6/20–6/23, 6/30–7/3, 7/5–7/13, 7/15–7/19, 7/21–7/25, 8/1, 8/28–9/11, 9/13–9/15, 9/17–9/22	**55.8** on 10/14	**7.1**

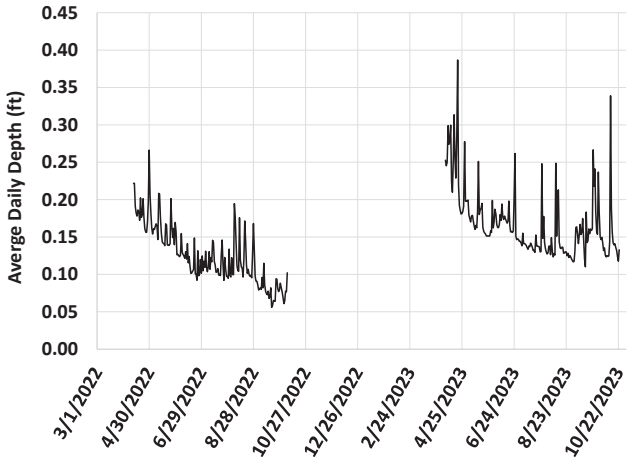

Figure 2 2022–2023 average daily depth at Plymouth Creek Station IP1

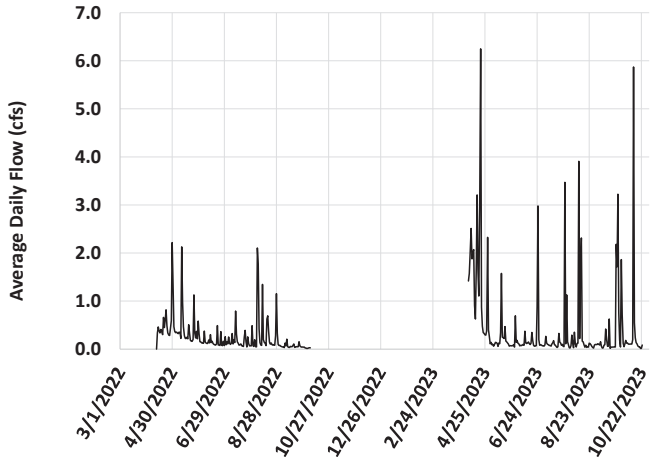

Figure 3 2022–2023 average daily flow at Plymouth Creek Station IP1

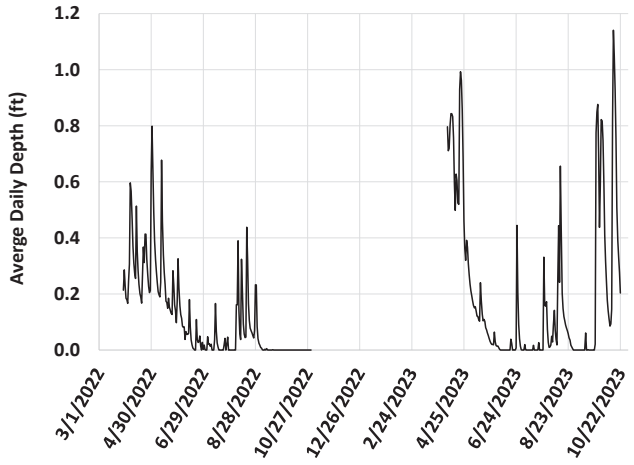

Figure 4 *2022–2023 average daily depth at Plymouth Creek Station IP2*

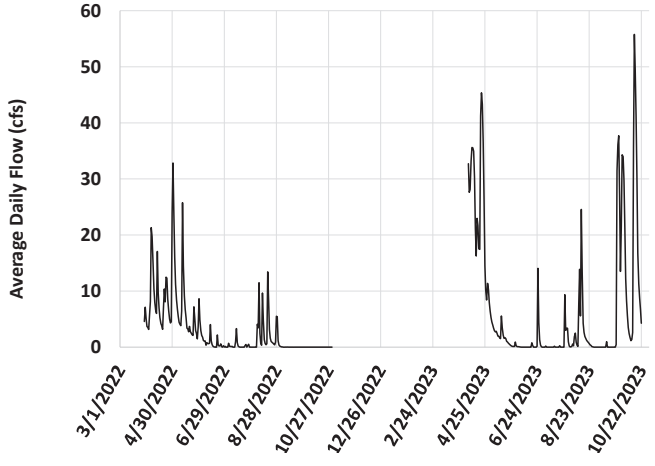

Figure 5 *2022–2023 average daily flow at Plymouth Creek Station IP2*

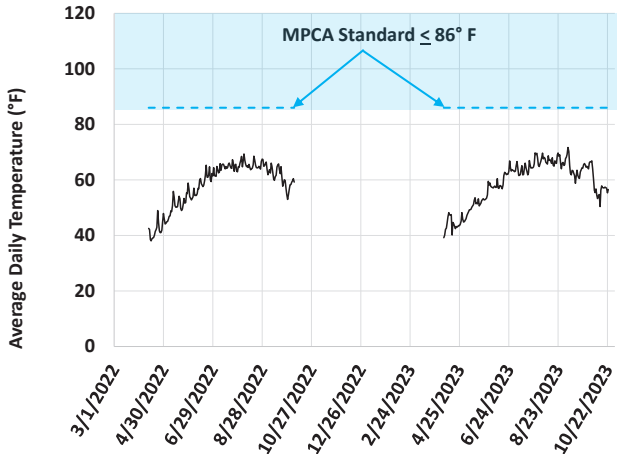

Figure 6 *2022–2023 average daily temperature at Plymouth Creek Station IP1*

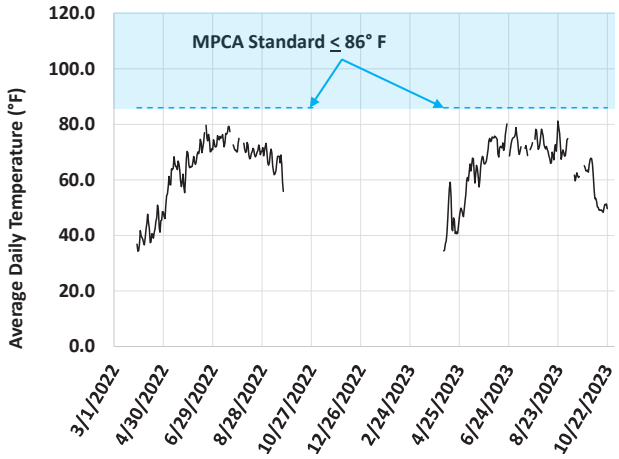

Figure 7 *2022–2023 average daily temperature at Plymouth Creek Station IP2*

Temperature

Temperature was measured at 15-minute intervals throughout the monitoring period from IP1 and IP2. During the 2022 monitoring period, the average daily temperature at IP1 ranged from 38 °F to 69 °F; the overall average was 58 °F (Figure 6). During the 2023 monitoring period, the average daily temperature at IP1 ranged from 39 °F to 72 °F; the overall average was 59 °F (Figure 6).

During the 2022 monitoring period, the average daily temperature at IP2 ranged from 34 °F to 80 °F; the overall average was 63 °F (Figure 7). During the 2023 monitoring period, the average daily temperature at IP2 ranged from 34 °F to 81 °F; the overall average was 64 °F (Figure 7).

All measurements from IP1 and IP2 met the MPCA standard of less than or equal to 86 °F. However, the MPCA is not currently using the standard to assess warm-water streams, such as Plymouth Creek, for temperature impairment. Instead, it evaluates mostly cold-water fisheries for temperature-caused impairment because of the sensitivity of cold-water fish to temperature elevations.

pH

The pH of water measures the degree of its acidic or alkaline reaction. The applicable pH standard for Plymouth Creek is a minimum of 6.5 and a maximum of 9.0. A stream meets the pH standard if it meets the standard at least 90 percent of the days of the monitoring season. A designation of meeting the standard for pH generally requires at least 20 suitable measurements from a data set that gives an unbiased representation of conditions over at least 2 different years.

The pH of Plymouth Creek was measured at IP1 and IP2 during 2022 and 2023. In 2022, the pH at IP1 ranged from 7.5 to 7.8; the overall average was 7.7. During 2023, the pH at IP1 ranged from 7.5 to 8.2, with an overall average of 7.7 (Figure 8). At IP2 the pH ranged from 7.2 to 8.1 in 2022, with an overall average of 7.4. In 2023, the pH of IP2 ranged from 7.2 to 8.1, and the overall average was 7.6 (Figure 9).

The 2022–2023 data included 23 pH measurements from location IP1 and 30 measurements from location IP2—all within the MPCA standard of 6.5 to 9.0. Hence, Plymouth Creek locations IP1 and IP2 met the MPCA pH standard.

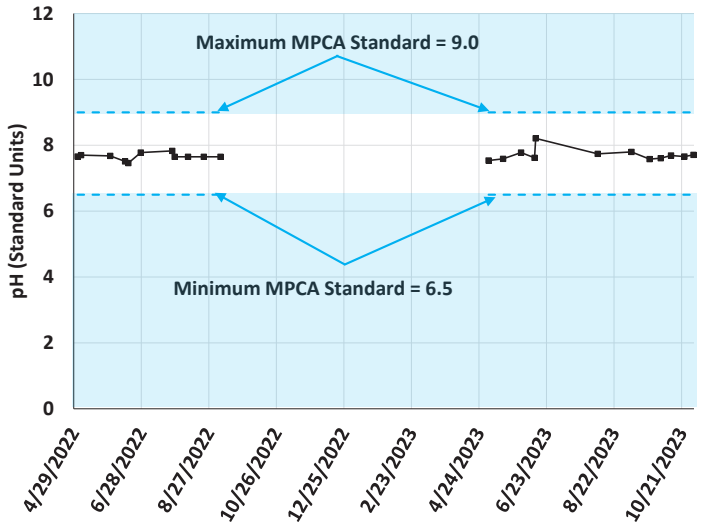

Figure 8 2022–2023 pH at Plymouth Creek station IP1

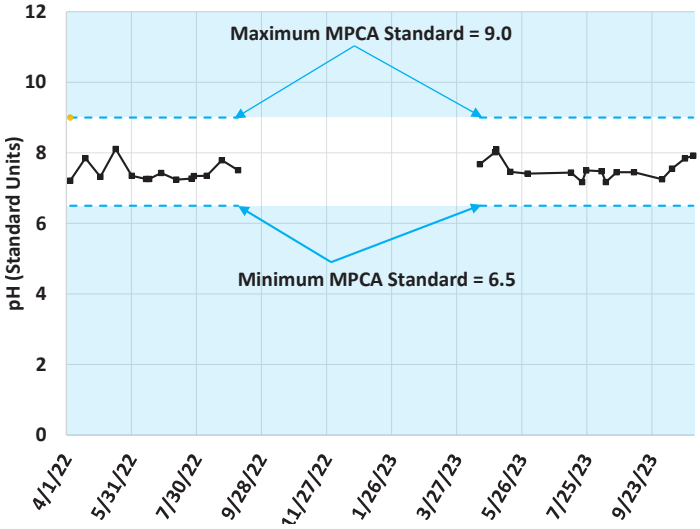

Figure 9 2022–2023 pH at Plymouth Creek station IP2

Dissolved Oxygen

Dissolved oxygen is required for all aquatic organisms to live. When dissolved oxygen drops below acceptable levels, desirable aquatic organisms, such as fish, can be harmed or killed. The MPCA dissolved oxygen standard for Plymouth Creek is at least 5 mg/L as a daily minimum. The stream meets the dissolved oxygen standard if at least 90 percent of the measurements are at least 5 mg/L and there are at least three such measurements. A designation of meeting the standard generally requires at least 20 measurements over at least 2 different years.

Dissolved oxygen was measured from two Plymouth Creek locations, IP1 and IP2, throughout the monitoring period. The measurements were instantaneous measurements, meaning a single measurement was taken during each sample event. During 2022, dissolved oxygen measurements from IP1 ranged from 7.6 to 11.3 mg/L; the overall average was 8.8 mg/L. During 2023, dissolved oxygen measurements from IP1 ranged from 5.7 to 11.4 mg/L; the overall average was 8.7 mg/L (Figure 10).

All 23 measurements made at IP1 during 2022–2023 met the MPCA standard of 5 mg/L. Because all measurements met the MPCA standard and at least 20 measurements were made over a 2-year period, Plymouth Creek at IP1 was not impaired for dissolved oxygen.

During 2022, dissolved oxygen measurements from IP2 ranged from 1.5 mg/L to 15.2 mg/L; the overall average was 7.2 mg/L. During 2023, dissolved oxygen measurements ranged from 0.5 to 14.6 mg/L; the overall average was 7.2 mg/L (Figure 11).

Ten of the 30 dissolved oxygen measurements (33 percent) at IP2 during 2022–2023 failed to meet the MPCA standard of 5 mg/L. These measurements generally occurred during periods of low or no flow (Figure 11). Plymouth Creek is not included on the 303(d) list of Minnesota's impaired waters for dissolved oxygen. However, because fewer than 90 percent of dissolved oxygen measurements from IP2 met the MPCA standard and at least 20 measurements were made over a 2-year period, Plymouth Creek at IP2 would be considered impaired for dissolved oxygen.

Dissolved oxygen concentrations for streams generally follow a diurnal cycle, with concentrations increasing during the day and decreasing overnight. When eutrophication causes undesirable levels of algae or rooted plants in a stream, the stream may respond with oxygen levels below 5 mg/L overnight due to excess removal of oxygen from the stream by plant respiration. Photosynthesis by plants during the day adds oxygen to the stream. This daily fluctuation in dissolved oxygen (lower levels at night and higher levels during the day) is termed DO flux.

Continuous dissolved oxygen was measured in Plymouth Creek at IP2 from August 12–18, 2022, and August 11–18, 2023, using a dissolved oxygen sensor/datalogger that collected dissolved oxygen measurements every 15 minutes during the measurement period. During 2022, measurements ranged from 4.57 to 8.57 mg/L; the overall average was 7.18 mg/L (Table 3). During 2023, dissolved oxygen measurements ranged from 6.44 to 8.44 mg/L; the overall average was 7.45 mg/L (Table 3). Only two of the 569 dissolved oxygen measurements (0.4 percent) in 2022 and none of the 727 dissolved oxygen measurements (0 percent) in 2023 failed to meet the standard of at least 5 mg/L. Because more than 90 percent of continuous dissolved oxygen measurements met the MPCA standard during 2022–2023 and more than 20 measurements were made over a 2-year period, continuous dissolved oxygen met the MPCA standard (Figure 12). However, continuous measurements were limited to a one-week period during each of two years. Because a third of the instantaneous (single) measurements taken throughout the two-year period failed to meet the MPCA standard, the stream would be considered impaired for dissolved oxygen despite the favorable continuous oxygen readings during the two weeks of measurement.

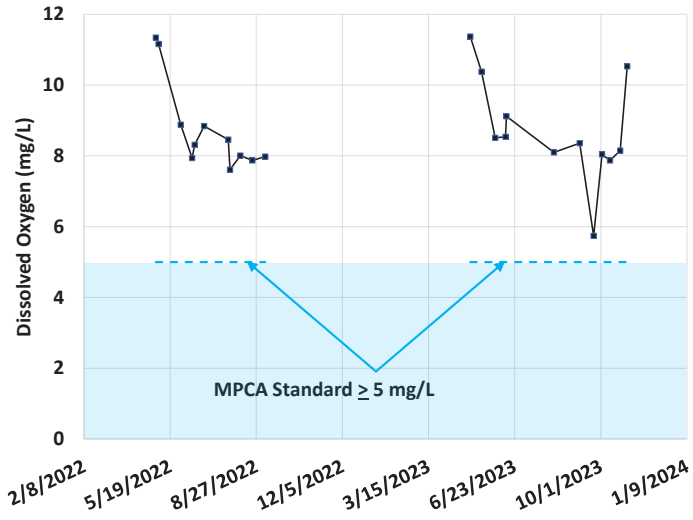

Figure 10 *2022–2023 dissolved oxygen at Plymouth Creek Station IP1*

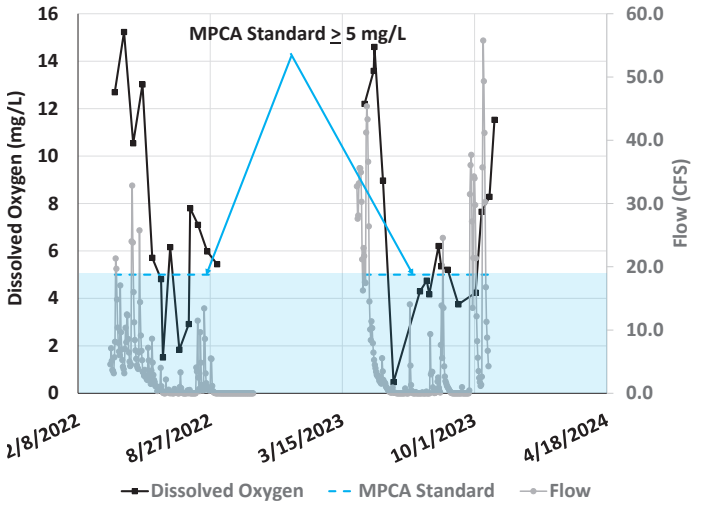

Figure 11 *2022–2023 dissolved oxygen and flow at Plymouth Creek Station IP2*

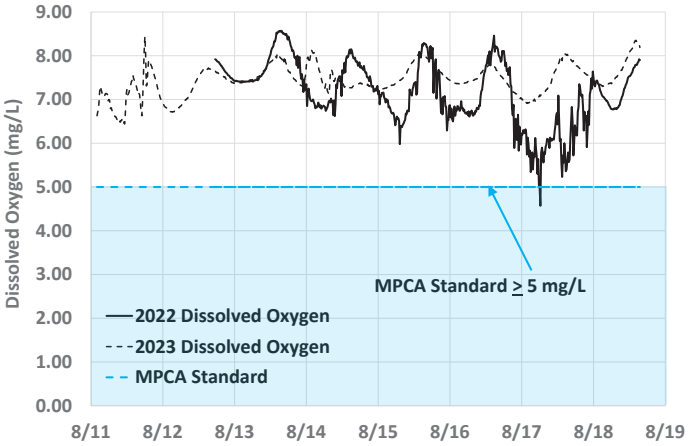

Figure 12 *2022–2023 continuous dissolved oxygen at Plymouth Creek Station IP2 from August 12–18, 2022, and August 11–18, 2023*

Total phosphorus, chlorophyll *a*, and dissolved oxygen (DO) flux

While phosphorus is necessary for plant and algae growth, too much phosphorus leads to excessive algae, decreased water clarity, and water quality impairment. Some common sources of phosphorus are fertilizers, leaves and grass clippings from streets, atmospheric deposition, soil erosion, and material from plant die-offs. The quantity of algae in water is measured by chlorophyll *a*, a pigment in algae. The MPCA standard for total phosphorus, chlorophyll *a*, and DO flux is the river eutrophication standard (RES). RES is a two-part standard, requiring an exceedance of the "causative variable" (total phosphorus) and a "response variable" (chlorophyll *a* or DO flux), which indicates the presence of eutrophication (excessive nutrients). Total phosphorus, chlorophyll *a*, and DO flux are considered in combination and not independently.

To determine whether a stream is impaired, total phosphorus and chlorophyll *a* data must be collected in at least two different years during a 10-year period; a minimum of 12 measurements per parameter (from June to September) must be used to determine the seasonal averages. The seasonal averages are then compared with the MPCA standard for each parameter: a maximum of 100 µg/L for total phosphorus and a maximum of 18 µg/L for chlorophyll *a*. For DO flux, a minimum 4-day deployment is required from June through September, with a minimum of two deployments over separate years. The MPCA standard for DO flux is a maximum of 3.5. The stream meets the RES if either the causative variable (total phosphorus) or response variables (chlorophyll *a* and DO flux) meet their respective standards.

Total phosphorus and chlorophyll *a* samples were collected from IP2 from April through August 2022 and April through October 2023. The 2022 through 2023 seasonal average (June through September) for the causative variable, total phosphorus (TP), was 216 µg/L, which failed to meet the MPCA RES standard (Figure 13). The 2022 through 2023 seasonal average for the response variable, chlorophyll *a*, was 7.6 µg/L, which met the MPCA RES standard (Figure 14).

DO flux was determined from continuous dissolved oxygen monitoring of IP2 from August 12–18, 2022, and August 11-18, 2023. DO flux ranged from 0.49 to 3.07 in 2022 which met the MPCA RES standard; the overall average was 1.91 (Figure 15 and Table 3). DO flux ranged from 0.75 to 2.00 in 2023 which met the MPCA RES standard; the overall average was 1.07 (Figure 15 and Table 3).

Although the causative variable, total phosphorus, failed to meet the MPCA standard, the two response variables, chlorophyll *a* and DO flux, both met the MPCA standard. Hence, the stream met the RES and is not considered impaired.

Table 3 *2022–2023 Summary of Continuous Dissolved Oxygen (DO) Measurements at Plymouth Creek Station IP2 from August 12–18, 2022, and August 11–18, 2023*

Date	Daily Average DO (mg/L)	Daily Maximum DO (mg/L)	Daily Minimum DO (mg/L)	Daily (Diel) DO Flux (mg/L)
8/12/2022	7.39	7.92	7.43	0.49
8/13/2022	7.82	8.57	7.17	1.40
8/14/2022	7.34	8.15	6.62	1.53
8/15/2022	7.17	8.29	5.98	2.31
8/16/2023	7.16	8.46	5.83	2.63
8/17/2022	6.14	7.64	4.57	3.07
8/18/2022	7.23	7.92	6.77	1.15
2022 Average	**7.18**	**8.17**	**6.27**	**1.91**
8/11/2023	7.04	8.44	6.44	2.00
8/12/2023	7.27	7.73	6.71	1.02
8/13/2023	7.59	8.05	7.30	0.75
8/14/2023	7.46	8.13	7.12	1.01
8/15/2023	7.61	8.04	7.22	0.82
8/16/2023	7.45	7.80	7.02	0.78
8/17/2023	7.47	8.05	6.91	1.14
8/18/2023	7.68	8.35	7.30	1.05
2023 Average	**7.45**	**8.07**	**7.00**	**1.07**

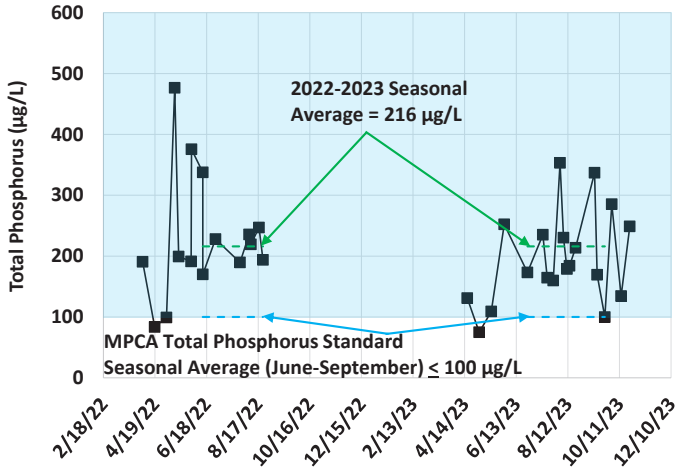

Figure 13 *2022–2023 total phosphorus at Plymouth Creek Station IP2*

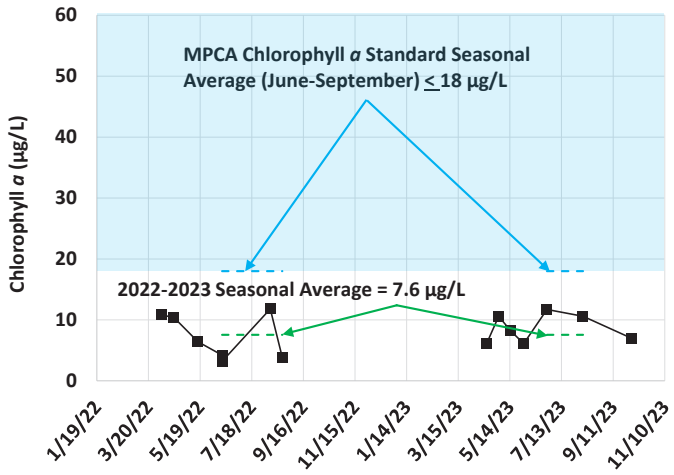

Figure 14 *2022–2023 chlorophyll a at Plymouth Creek Station IP2*

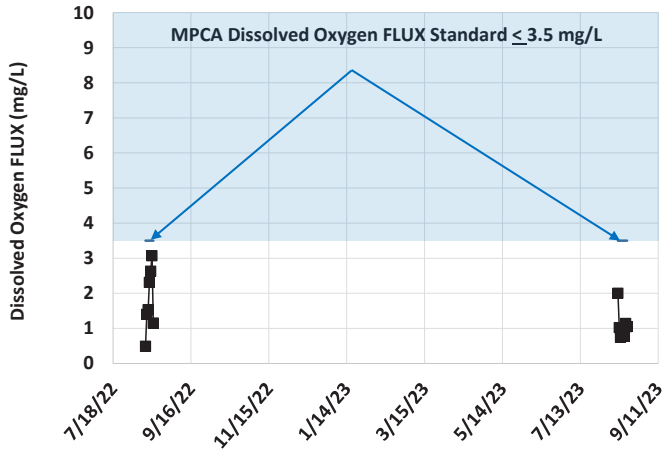

Figure 15 2022–2023 dissolved oxygen FLUX at Plymouth Creek Station IP2

Chlorides

Chloride concentrations in area streams have increased since the early 1990s when many government agencies switched from sand or sand/salt mixtures to salt for winter road maintenance. When snow and ice melt, the salt goes with it, washing into lakes, streams, wetlands, and groundwater. It only takes 1 teaspoon of road salt to pollute 5 gallons of water such that it can no longer support freshwater life. And that pollution is essentially permanent as there is no easy or affordable way to remove chloride from the water.

Because high chloride concentrations can harm fish and plant life, the MPCA has established maximum and chronic chloride standards. The maximum standard is the highest concentration of chloride that aquatic organisms can be exposed to for a brief time with zero-to-slight mortality. The chronic standard is the highest chloride concentration that aquatic life can be exposed to indefinitely without causing chronic toxicity. Chronic toxicity is defined as a stimulus that lingers or continues for a long period, often one-tenth the life span or more. A chronic effect can be mortality, reduced growth, reproduction impairment, harmful changes in behavior, and other nonlethal effects. A lake is considered impaired if two or more measurements exceed the chronic criterion (230 mg/L) within 3 years or if one measurement exceeds the maximum criterion (860 mg/L).

Chloride was measured from IP1 and IP2 during 2022 and 2023. In 2022, chloride concentrations at IP1 ranged from 14 mg/L to 382 mg/L; the overall average was 163 mg/L. Three of the 12 measurements exceeded the MPCA chronic chloride standard of 230 mg/L. In 2023, chloride concentrations at IP1 ranged from 0 mg/L to 588 mg/L; the overall average was 146 mg/L. Four of the 16 measurements exceeded the MPCA chronic chloride standard of 230 mg/L (Figure 16).

In 2022, chloride concentrations at IP2 ranged from 66 mg/L to 258 mg/L; the overall average was 172 mg/L. Four of the 13 measurements exceeded the MPCA chronic chloride standard of 230 mg/L. In 2023, chloride concentrations in IP2 ranged from 42 mg/L to 444 mg/L; the overall average was 204 mg/L. Three of the 10 measurements exceeded the MPCA chronic chloride standard of 230 mg/L (Figure 17).

Specific-conductance data was analyzed to provide additional information about chloride concentrations. Specific conductance measures how well water can conduct electricity. It indicates what is dissolved in the water and increases with larger numbers of ions, including chloride ions. A linear regression analysis of specific conductance and chloride measurements from IP2 indicated that 78 percent of the specific-conductance value was due to chloride ions in the stream. The outcome of the linear regression analysis was a regression equation, which is a statistical model of the relationship between specific conductance and chloride. The model was used to estimate average daily chloride values from the average daily specific-conductance values. In 2022, the estimated average daily chloride concentrations at IP2 ranged from 37 mg/L to 305 mg/L, with an average of 199 mg/L (Figure 17). The estimated number of days that chloride concentrations exceeded the MPCA standard in 2022 was 41 of the 128 days of specific-conductance measurements (32 percent, Figure 17). In 2023, the estimated average daily chloride concentrations at IP2 ranged from 9 mg/L to 468 mg/L, with an average of 239 mg/L (Figure 17). The estimated number of days that chloride concentrations exceeded the MPCA standard was 69 of the 138 days of specific-conductance measurements (50 percent, Figure 17).

Plymouth Creek has been listed on the 303(d) list of Minnesota's impaired waters for chloride since 2014. Because chloride concentrations in samples collected from Plymouth Creek locations IP1 and IP2 exceeded the MPCA standard on more than two occasions during the 2022 and 2023 monitoring period, the stream was impaired for chlorides.

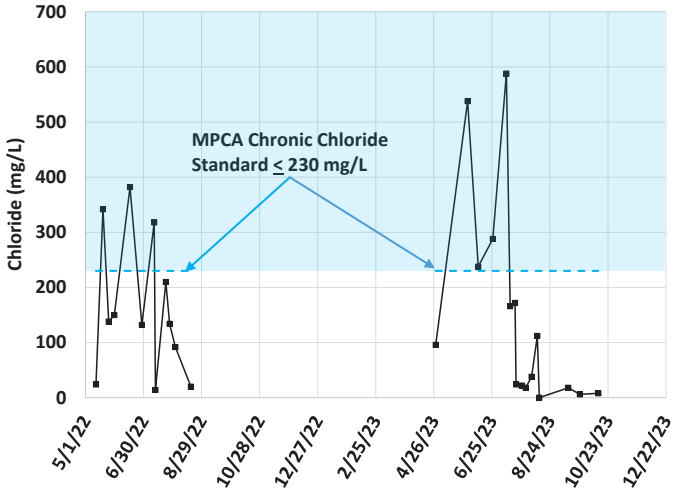

Figure 16 *2022–2023 measured chloride concentrations at Plymouth Creek Station IP1*

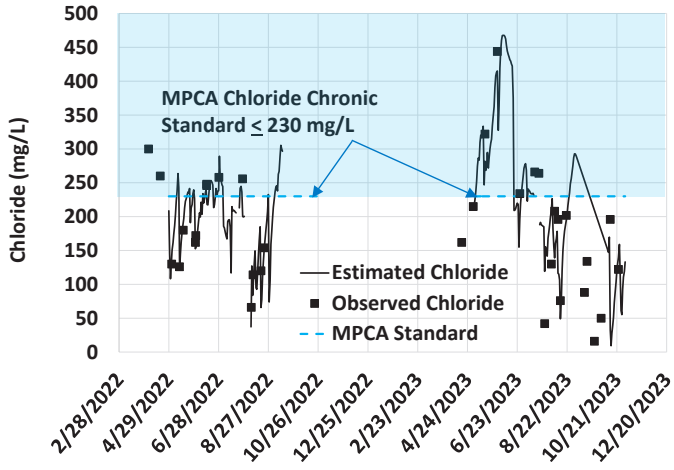

Figure 17 *2022–2023 chloride concentrations: measured and estimated from average daily specific-conductance measurements at Plymouth Creek Station IP2*

E. coli Bacteria

The Environmental Protection Agency (EPA) determined that E. coli is the preferred indicator of the potential presence of waterborne pathogens. The MPCA standard for E. coli protects streams used for two types of recreation: primary body contact (e.g., swimming, where inadvertent ingestion of water is likely) and secondary body contact (e.g., wading, where the likelihood of ingesting water is much smaller). The MPCA uses average and maximum E. coli values to determine impairment. E. coli standards are applicable only during the warmer months of April through October since swimming or wading in Minnesota streams during the November through March period is not expected.

Average E. coli is assessed by a standard based on a geometric mean EPA criterion of 126 E. coli colony-forming units (cfu) per 100 mL. Data are aggregated by individual month (e.g., all April values, all May values, etc.) for up to 10 years to determine impairment due to high average monthly E. coli values. At least 3 months of data must be collected, preferably between June and September, and at least five values must be collected per month for those 3 months (15 samples) to determine impairment due to high average E. coli.

If the geometric mean of the aggregated monthly values for one or more months exceeds 126 cfu per 10 mL, the reach is considered impaired. E. coli data collected at IP2 from 2022 through 2023 were assessed to determine whether average E. coli values met the MPCA impairment standard. The April, May, June, August, and October monthly geometric means from the aggregated 2022 through 2023 values ranged from a low of 50 cfu per 100 mL in April to a high of 1,061 cfu per 100 mL in August (Figure 18). Geometric means during May, June, August, and October failed to meet the MPCA standard of 126 cfu per 100 mL (Figure 18). However, because the geometric means were computed from one or two samples per month, Plymouth Creek would not be considered impaired for E. coli bacteria because fewer than five samples per month were collected for at least 3 months. Insufficient information prevented assessment of Plymouth Creek for E. coli impairment using geometric means.

The MPCA also considers a water body impaired for aquatic recreation if more than 10% of individual values exceed 1,260 E. coli organisms per 100 milliliters (maximum E. Coli standard). All E. coli sample values from Plymouth Creek location IP2 in 2022 and 2023 met this MPCA standard (Figure 19).

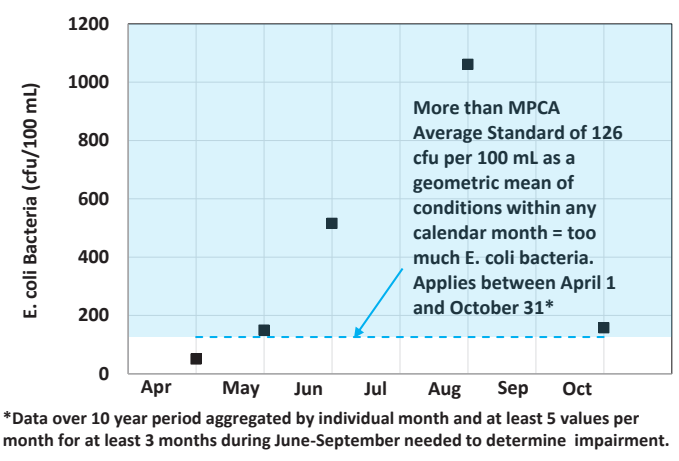

Figure 18 *2022–2023 monthly geometric means of E. coli bacteria at Plymouth Creek Station IP2*

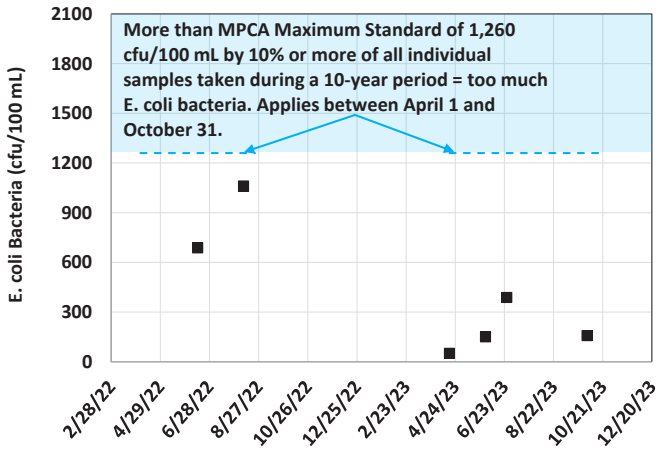

Figure 19 2022–2023 E. coli bacteria at Plymouth Creek Station IP2

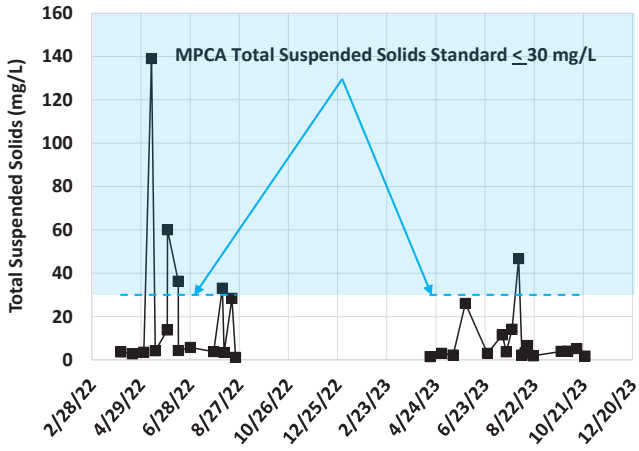

Figure 20 2022–2023 total suspended solids at Plymouth Creek Station IP2

Total Suspended Solids

Total suspended solids consist of soil particles, algae, and other materials that are suspended in water and cause a lack of clarity. Excessive total suspended solids can harm aquatic life and degrade aesthetic and recreational qualities. A stream is considered to exceed the standard for total suspended solids (30 mg/L) if (1) the standard is exceeded more than 10 percent of the days of the assessment season (April through September) and (2) there are at least three such measurements exceeding the MPCA standard (30 mg/L).

In 2022, total suspended solids concentrations from IP2 ranged from a low of 1.1 mg/L on August 22 to a high of 139 mg/L on May 11 (Figure 20). The average during the April through August assessment period was 22.9 mg/L. Four of the 15 samples collected during this period (27 percent) exceeded the MPCA standard of 30 mg/L (Figure 20).

In 2023, total suspended solids concentrations from IP2 ranged from a low of 1.5 mg/L on April 17 to a high of 46.7 mg/L on August 3 (Figure 20), the average during the April through September assessment season was 9.3 mg/L. One of the 14 samples collected during this period (7 percent) exceeded the MPCA standard of 30 mg/L (Figure 20).

Plymouth Creek is not currently included on the 303(d) list of Minnesota's impaired waters for total suspended solids. However, because the total suspended solids standard was exceeded in more than 10 percent of the samples collected from IP2 during the 2022 assessment season (April through September), and there were at least three measurements, the stream would be considered impaired for total suspended solids.

Metals

Metals are naturally occurring elements found throughout the earth's crust. Their multiple industrial, domestic, agricultural, medical, and technological applications have led to their widespread distribution in the environment. Because heavy-metal-induced toxicity can harm aquatic life, the MPCA has established three standards for Class 2B waters—chronic, maximum, and final acute values (FAVs)—for each metal type. (The MPCA has classified Plymouth Creek as a Class 2B water.) The chronic standard (CS) is the highest toxicant concentration that aquatic organisms can be indefinitely exposed to without harmful effects. The maximum standard (MS) is a concentration that protects aquatic organisms from the potentially lethal effects of a short-term "spike" in toxicant concentrations. The MS is always equal to one-half of the FAV: the concentration that would kill about one-half of the exposed individuals of a very sensitive species. The FAV is most often used as an "end-of-pipe" effluent limit to prevent the discharge of acutely toxic substances into streams. Because increases in water hardness decrease the toxicity of metals, the MPCA metals standards vary with water hardness. To show this variation, metal concentrations in Figures 21–26 are plotted on the y-axis and hardness on the x-axis.

Quarterly samples were collected from IP2 and analyzed for total cadmium, total chromium, copper, nickel, lead, and zinc during the 2022 and 2023 monitoring periods. All samples met the MPCA standards, indicating metals are not causing toxicity to aquatic organisms in the stream.

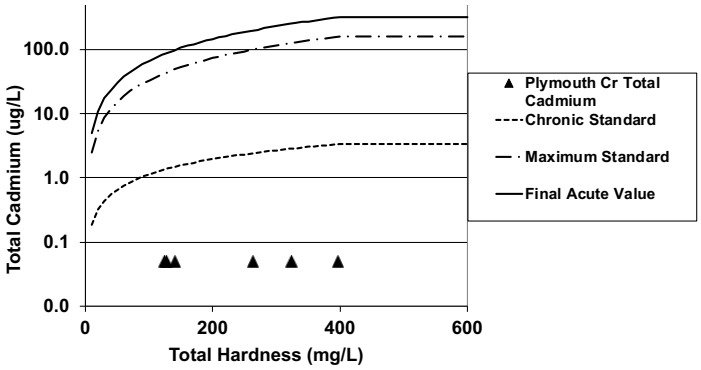

Figure 21 *2022–2023 total cadmium at Plymouth Creek Station IP2 compared to MPCA standards*

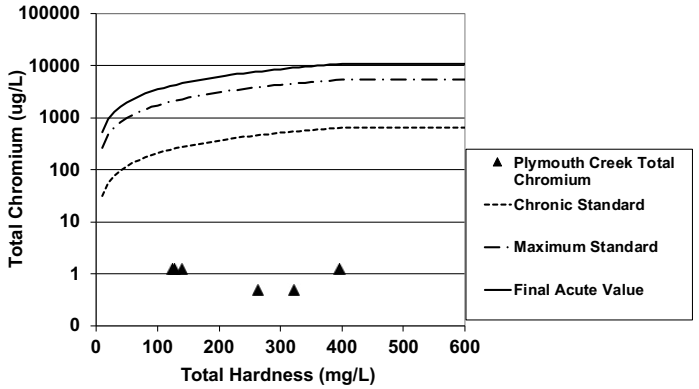

Figure 22 *2022–2023 total chromium at Plymouth Creek Station IP2 compared to MPCA standards*

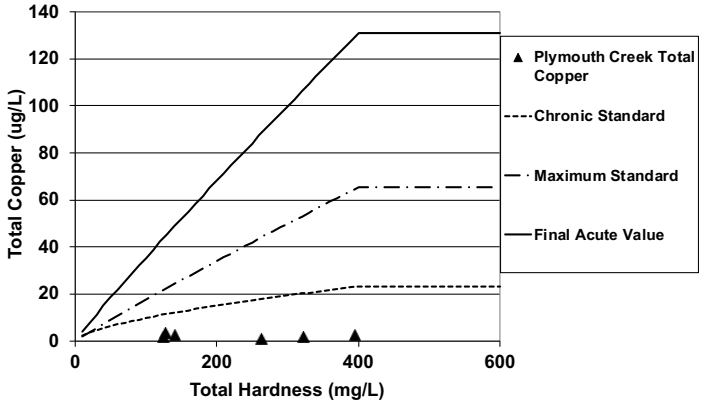

Figure 23 *2022–2023 total copper at Plymouth Creek Station IP2 compared to MPCA standards*

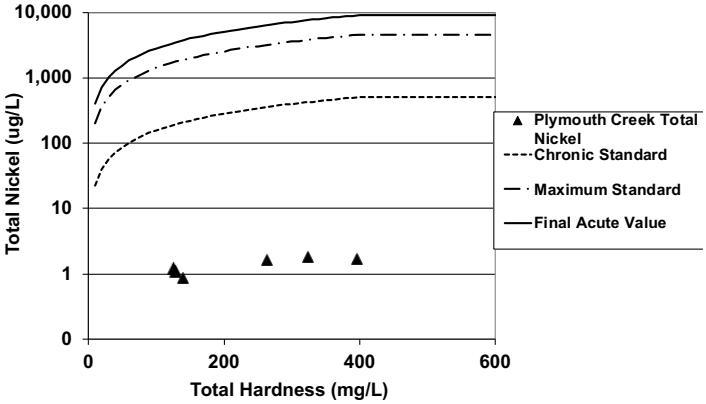

Figure 24 *2022–2023 total nickel at Plymouth Creek Station IP2 compared to MPCA standards*

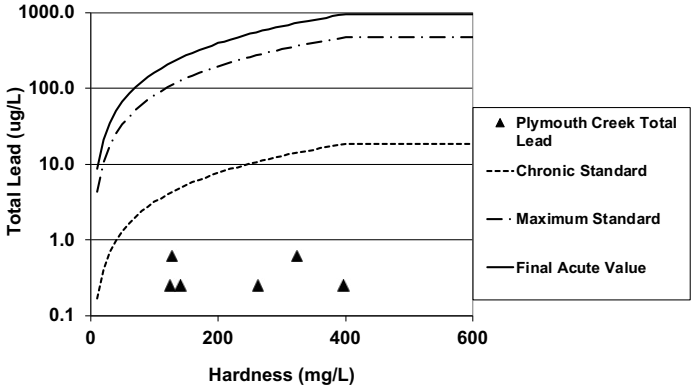

Figure 25 *2022–2023 total lead at Plymouth Creek Station IP2 compared to MPCA standards*

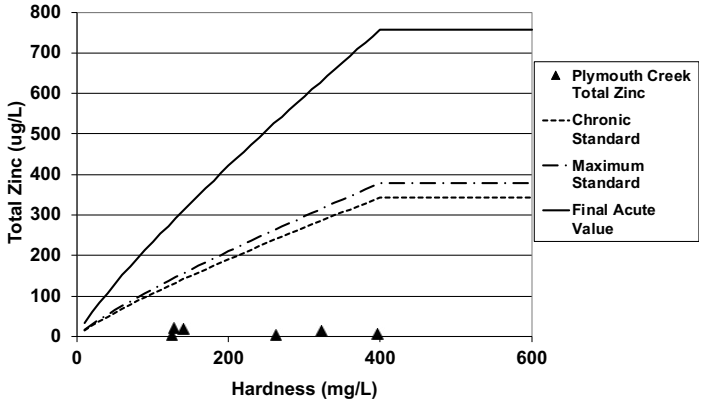

Figure 26 *2022–2023 total zinc at Plymouth Creek Station IP2 compared to MPCA standards*

Biotic Index Evaluation of Plymouth Creek

In 2022, the BCWMC monitored Plymouth Creek for benthic macroinvertebrates (bottom-dwelling organisms) and assessed the stream's habitat (see Figure 1 for sampling locations). This sampling has been done on 11 occasions between 1980 and 2022 to evaluate water quality and detect changes over time. The Macroinvertebrate Index of Biotic Integrity (M-IBI) was used to evaluate the health of the stream's macroinvertebrate community. The Minnesota Pollution Control Agency (MPCA) developed the M-IBI and added it to Minnesota's water quality standards to help identify biologically impaired rivers and streams.

Plymouth Creek Habitat

Habitat is a key factor in determining the presence and distribution of macroinvertebrates in streams. Stream macroinvertebrates are influenced by such habitat factors as substrate size and composition, the quantity of fine sediment deposited on the substrate, and the presence of vegetation. The substrate provides places for food and refuge for macroinvertebrates. Aquatic vegetation provides shelter against predation by small fish. Adverse changes in habitat can result in adverse changes to the macroinvertebrate community.

Habitat surveys of Plymouth Creek at Industrial Boulevard were completed in 2015 and 2022 using the MPCA quantitative habitat survey method. The survey results are summarized in Table 4. Changes between the 2015 and 2022 habitat evaluations include increases in depth of fine sediment, length of bank erosion, and amount of algae. Dry climatic conditions in 2022 resulted in decreases in flows and water depth.

M-IBI

The MPCA has established biological water quality standards for all Minnesota streams and rivers, including Plymouth Creek. An M-IBI and a fish index of biotic integrity (F-IBI) were added to Minnesota standards and approved by the United States Environmental Protection Agency on June 26, 2018.

The M-IBI helps identify biologically impaired rivers and streams by assessing the health of their macroinvertebrate communities. The M-IBI score is the sum of the scores from 10 individual metrics. Each metric assesses an attribute of the macroinvertebrate community; collectively, the metrics assess the community's overall health. Each M-IBI metric has a scale of 0 to 10; the lowest possible score is 0, and the highest is 10. Increasing scores indicate improving conditions. Because 10 metrics are summed to attain the M-IBI score, and each metric has a maximum score of 10, the maximum possible score is 100. To meet the MPCA macroinvertebrate standard, the sum of the scores from the 10 individual metrics must equal or exceed the impairment threshold— the MPCA Macroinvertebrate

Table 4 2015 and 2022 Habitat Comparison: Plymouth Creek at Industrial Boulevard

Parameter	Plymouth	
	2015	2022
Discharge (flow) (cfs)1	0.2	0.1
Average depth of water (cm)	15	11
Average depth of fine sediment (cm)	1.3	1.4
Average embeddedness of coarse sediment (%)	52	52
Percent of transects with left-bank erosion	38	38
Percent of transects with right-bank erosion	8	8
Average length of bank erosion per transect: left bank (m)	0.2	0.5
Average length of bank erosion per transect: right bank (m)	0.0	0.5
Average amount of algae (filamentous or attached) observed on quadrate (%)	12	39
Average number of macrophytes observed on quadrate (%)	0	0
Percent length of transect over at least 10 cm of water with overhanging vegetation	0	0
Percent length of transect over at least 10 cm of water with submerged vegetation	0	0
Percent length of transect over at least 10 cm of water with emergent vegetation	0	0
Percent length of transect over at least 10 cm of water with woody debris	0	0
Percent length of transect over at least 10 cm of water with boulders	8.2	2.1
Percent length of transect over at least 10 cm water depth with undercut banks	0	0

[1]Discharge when macroinvertebrate samples **were collected.**

Class 5 (Southern Streams) standard of 37 is applicable to Plymouth Creek.

The BCWMC collected macroinvertebrate samples from Plymouth Creek on September 28, 2022, and computed the M-IBI score to determine whether the stream met the M-IBI biological standard. The 2022 M-IBI score of 14 did not meet the M-IBI biological standard (Figure 27).

Macroinvertebrate data collected by BCWMC from 1991 through 2022 and by the MPCA in 2010 and 2020 were evaluated using the M-IBI. All M-IBI scores were compared with the MPCA standard. None of the M-IBI scores met the MPCA standard. BCWMC M-IBI scores ranged from a low of 13 to a high of 32 (Figure 27). The MPCA scores ranged from 7.7 in 2020 to 24.9 in 2010. Both MPCA scores were below the MPCA standard, resulting in Plymouth Creek being added to Minnesota's impaired waters list for aquatic life-benthic macroinvertebrates bioassessments in 2024. Macroinvertebrate data collected by BCWMC from 1991 through 2022 support the inclusion of Plymouth Creek on Minnesota's impaired waters list.

The MPCA completed a Stressor Identification (SID) for Plymouth Creek in 2024 to determine stressors causing biological impairment in the stream. The most common stressor found was altered hydrology and connectivity followed by eutrophication due to excess total phosphorus, inadequate dissolved oxygen, excess

chloride, and excess total suspended solids. The 2022–2023 Plymouth Creek data were consistent with MPCA findings, with inadequate dissolved oxygen, excess chloride, excess total suspended solids, and excess total phosphorus. The 2022–2023 Plymouth Creek data also identified inadequate flow as a stressor to the biological community. Dry climatic conditions in 2022 and 2023 resulted in no flow at:

- Plymouth Creek monitoring location Industrial Park 1 (IP1) during 12 percent of the monitored period in 2022 and 13 percent of the monitored period in 2023.
- Plymouth Creek monitoring location Industrial Park 2 (IP2) during 40 percent of the monitored period in 2022 and 33 percent of the monitored period in 2023.

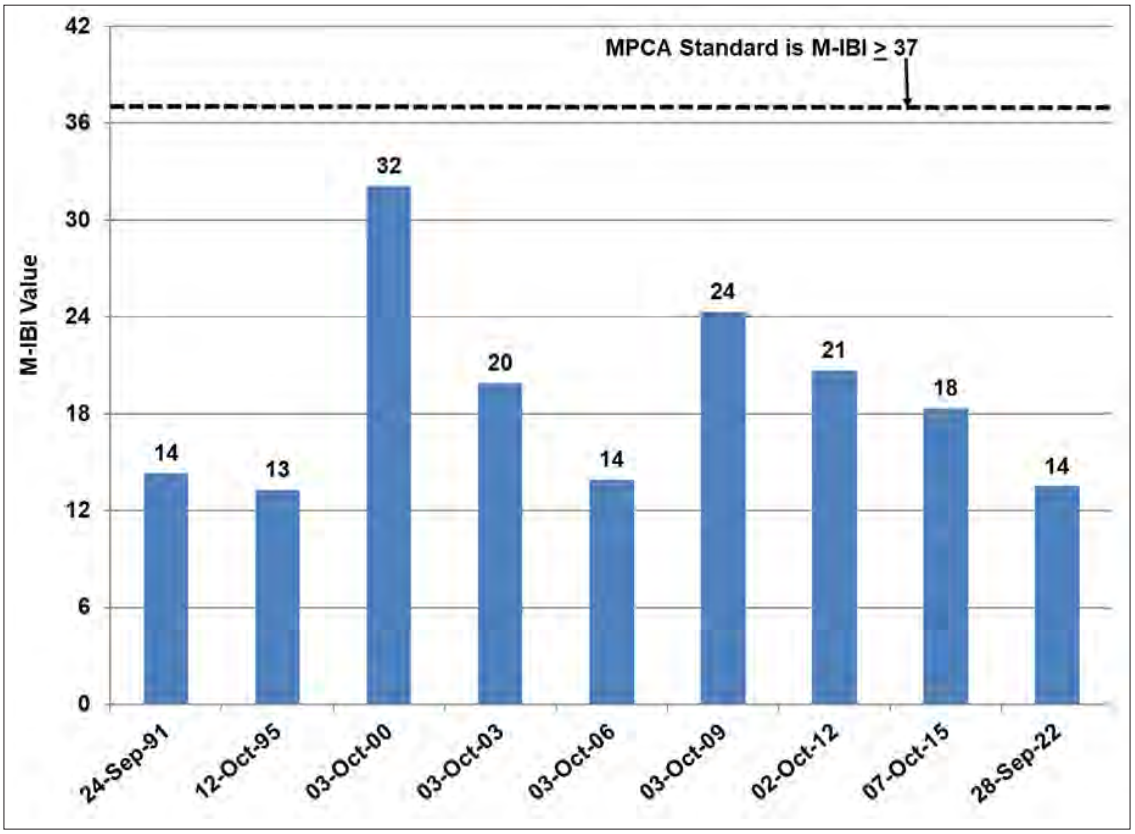

Figure 27 1991–2022 M-IBI Metric Scores from the Plymouth Creek Biological Monitoring Station

Bassett Creek Watershed Management Commission
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Stewardship of water resources to protect and enhance our communities