City of Waukesha

Diversion Approval Report for 2024

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Waukesha Water Utility and the Clean Water Plant on behalf of the City of Waukesha

Supported By:

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Acronyms and Abbreviations

BPS	booster pumping station in Waukesha
CEM	conservation and efficiency measure
CWP	Clean Water Plant
gpd	gallons per day
MWW	Milwaukee Waterworks
REU	residential equivalency unit
USGS	U.S. Geological Survey
WBR	winter-based rate
WDNR	Wisconsin Department of Natural Resources
WPSC	Wisconsin Public Service Commission
WWU	Waukesha Water Utility

The June 21, 2016, Final Decision approving the Application by the City of Waukesha, Wisconsin (City), for a Diversion of Great Lakes Water from Lake Michigan and an Exception to Allow the Diversion sets forth various conditions of the approval.

Condition J of the Final Decision requires an annual report to be filed that "documents the daily, monthly, and annual amounts of water diverted and returned to the Lake Michigan watershed over the previous calendar year." The City of Waukesha continued its diversion for all of 2024, thereby requiring reporting as specified in the Final Decision and the Wisconsin Department of Natural Resources (WDNR) June 29, 2021, Diversion Approval. This report satisfies the requirements and mirrors the lettering format of the Diversion Approval, Section 12, *Reporting* (Diversion Approval, page 10).

A. Compact Principles

Requirement: The City shall summarize that the diversion was implemented consistent with the requirements of the Council Decision.

On October 9, 2023, the Waukesha Water Utility (WWU) completed its commissioning and testing of new equipment and began the initial transition to Milwaukee Waterworks (MWW) water. By November 2, 2023, the final transition was complete. Following the completion of the transition, and for all of 2024, WWU has continued to purchase water from MWW for distribution to its customers.

On November 8, 2023, and April 8, 2024, radionuclide sampling required by WDNR was completed. The results of those sampling events were received on December 20, 2023, and May 1, 2024, respectively, and were all less than the limit of detection for reporting the results.

The WWU has an approved extended well abandonment agreement signed by all parties on November 28, 2023, for all previously active wells, thus changing their status from active to emergency use. The groundwater pumped in 2024 was minimal, only what was needed to complete the sampling required by WDNR, and it was pumped to waste.

B. City of Milwaukee Water Supply Volumes

Requirement: The total amount of water purchased daily, monthly, and annually from the City of Milwaukee, including the location(s) of the water meter used to determine the amount of water purchased.

The water purchased from MWW is measured by a meter in the pit near the Oklahoma Pump Station in Milwaukee. The annual total of purchased water from MWW for 2024 is 1,844,782,000 gallons. The daily water volume of purchased MWW water is included in Appendix A. The monthly water volume of purchased MWW water is summarized in Table B-1.

Table B-1. Monthly Water Purchased from Milwaukee Waterworks

Month	Pumpage from Groundwater (gallons)	Water Purchased from MWW for Drinking (gallons)
January 2024	0	152,757,400
February 2024	0	146,169,900
March 2024	0	148,684,700
April 2024	0	144,622,600
May 2024	0	154,149,400
June 2024	0	157,387,400

Month	Pumpage from Groundwater (gallons)	Water Purchased from MWW for Drinking (gallons)
July 2024	0	162,912,700
August 2024	0	167,367,700
September 2024	0	163,164,900
October 2024	0	155,411,100
November 2024	0	143,243,300
December 2024	0	148,910,900
2024 Total	0	1,844,782,000

C. Water Sales Volumes

Requirement: The total amount of water sold monthly to each category of customer within the approved diversion area.

The City sold a total of 1,648,585,700 gallons of water in 2024 to its customers, all of which was purchased from MWW. The total sold volume is less than the total pumpage volume (1,844,782,000), where the difference includes water-using activities such as hydrant and main flushing, equipment maintenance, water main breaks, and water used for the various water quality analyzers.

Table C-1 summarizes the water sales volumes, by month and customer class, for 2024.

Table C-1. 2024 Monthly Water Sales Volumes in Gallons by Customer Class

Customer Class	# of Customers	Jan	Feb	Mar	Apr	May	Jun
RESIDENTIAL	17,032	57,171,000	57,793,200	56,918,900	55,021,100	52,326,700	58,976,300
RES-2 FAMILY	1,228	7,667,500	7,699,000	7,539,400	7,599,200	6,964,500	7,518,100
RES-3 FAMILY	76	536,500	531,300	582,100	532,200	476,600	501,200
MULTI-FAMILY	948	28,578,700	28,721,800	28,609,700	28,365,800	25,681,900	27,352,800
COMMERCIAL-REG	1,271	23,706,500	22,365,100	24,710,200	25,499,700	22,579,300	25,999,300
INDUSTRIAL	143	11,301,500	10,974,300	12,848,200	11,682,600	10,108,600	12,770,300
PUBLIC	117	3,531,000	3,915,900	4,265,200	3,732,500	4,058,200	6,425,200
IRRIGATION	174	4,700	600	900	3,000	14,100	162,100
TOTAL	**20,989**	**132,497,400**	**132,001,200**	**135,474,600**	**132,436,100**	**122,209,900**	**139,705,300**

Customer Class	Jul	Aug	Sep	Oct	Nov	Dec	Total
RESIDENTIAL	63,071,400	57,120,900	60,421,500	63,601,000	59,893,400	55,597,000	**697,912,400**
RES-2 FAMILY	7,875,800	7,110,800	7,271,000	7,770,800	7,431,600	7,330,500	**89,778,200**
RES-3 FAMILY	544,500	497,400	548,000	713,700	692,700	578,800	**6,735,000**
MULTI-FAMILY	29,083,700	26,473,300	28,051,800	30,578,400	29,872,500	29,264,800	**340,635,200**
COMMERCIAL-REG	30,471,800	26,916,000	30,440,600	34,146,600	26,361,800	24,593,500	**317,790,400**
INDUSTRIAL	10,652,500	10,738,600	12,450,600	11,782,400	11,911,900	8,851,000	**136,072,500**
PUBLIC	4,411,700	4,592,000	4,985,400	5,528,900	4,481,000	4,215,500	**54,142,500**
IRRIGATION	417,500	842,200	1,267,600	1,733,300	809,800	263,700	**5,519,500**
TOTAL	**146,528,900**	**134,291,200**	**145,436,500**	**155,855,100**	**141,454,700**	**130,694,800**	**1,648,585,700**

D. Return Flow Volumes

Requirement: The daily, monthly, and annual volume of treated wastewater discharge returned to the Root River and the daily, monthly, and annual volume of treated wastewater discharge returned to the Fox River.

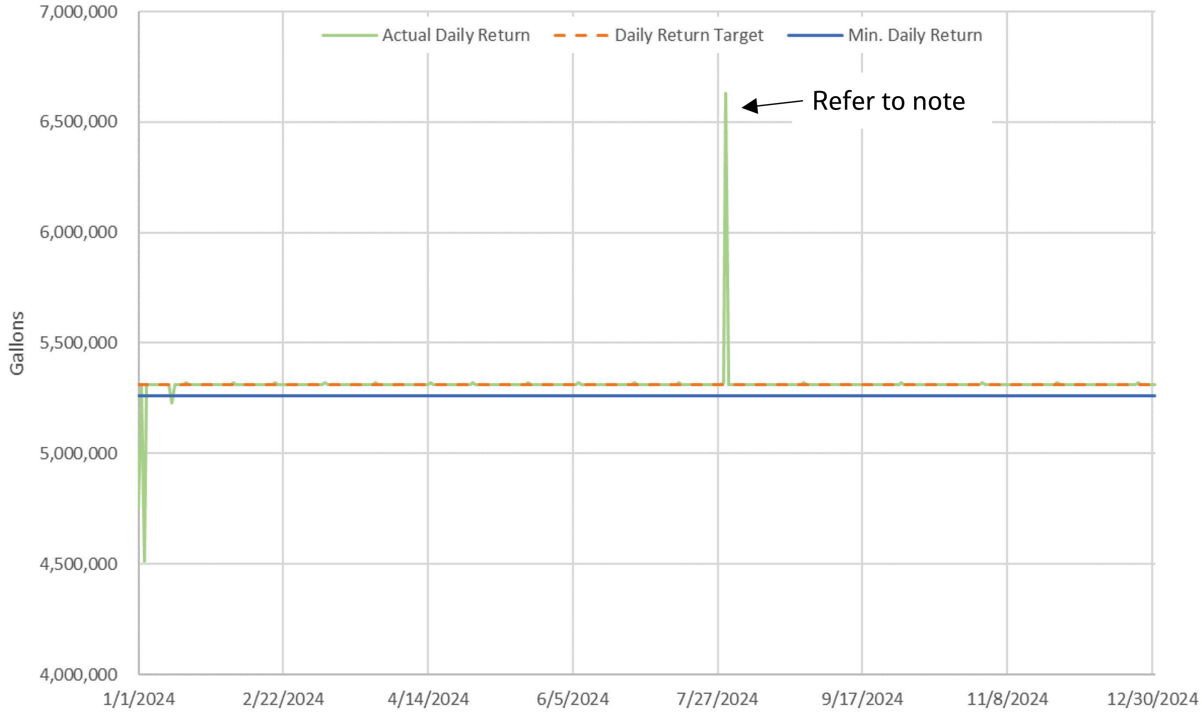
The City continued normal operation of the return flow pump station throughout 2024, with the majority of treatment plant flow to the Root River and the balance of the total plant flow to the Fox River (Table D-1). The 2023 average daily water demand was 5.26 million gallons, which was the daily return flow requirement in 2024. Similar to return flow in 2023, an additional 0.05 million gallons of daily return flow was set in the pump station controls to provide a margin of safety to meet daily return flow volumes while staff continue to gain familiarity with the return flow infrastructure. This resulted in a daily return flow target of 5.31 million gallons. Following the same pump station control logic as 2023, after 5.31 million gallons were measured by the Clean Water Plant (CWP) magmeter, the pumps shut down until midnight. When midnight arrived, the pumps restarted to return 5.31 million gallons, and this cycle repeated itself each day. The additional 0.05 million gallons greater than the requirement may be changed in 2025 as the plant staff become more familiar with the pump station operation and are confident about meeting the daily return flow volume requirement.

Table D-1. Monthly Volumes Discharged to the Root and Fox Rivers

Month	Fox River Discharge Volume (gallons)	Root River Discharge Volume (gallons)	Total Clean Water Plant Discharge Volume (gallons)
January	71,520,000	163,180,000	234,700,000
February	102,374,000	154,010,000	256,384,000
March	159,481,000	164,630,000	324,111,000
April	231,330,000	159,320,000	390,650,000
May	166,561,000	164,620,000	331,181,000
June	231,805,000	159,320,000	391,125,000
July	164,930,000	165,950,000	330,880,000
August	103,223,000	164,620,000	267,843,000
September	70,299,000	159,300,000	229,599,000
October	50,839,000	164,630,000	215,469,000
November	56,376,000	159,310,000	215,686,000
December	46,889,000	164,620,000	211,509,000
Annual Total	1,455,627,000	1,943,510,000	3,399,137,000

The daily return flow requirement was achieved on 363 of the 366 days (99.2% of days) and, while not a diversion requirement, the City also was able to return slightly more water (5.4%) than the 2024 water withdrawal. A summary of the daily return flow and the three days when daily flow was less than the requirement is summarized on Figure D-1 and in Table D-2. The daily return flow volumes are included in Appendix B.

Figure D-1. 2024 Daily Return Flow and Targets



Note: On July 30, 2024, the return flow pumping mode was inadvertently switched. It was returned to its normal operating mode the next day.

Table D-2. 2024 Days Less Than Return Flow Target

Date	Return Volume Deficit to Requirement (gallons)	Comment
1/1/2024	-510,000	Return flow gate malfunction resulted in pumps shutting down. Alarm did not alert plant staff.
1/3/2024	-750,000	Return flow gate limits malfunction in the morning. Manufacturer representative onsite to correct issue.
1/13/2024	-30,000	Fox River gate malfunctioned causing pumps to not turn on. Manufacturer representative was onsite 1/18 to correct.

The U.S. Geological Survey (USGS) continued operation of temporary redundant area-velocity meters in the return flow outfall building throughout 2024 to compare against the daily return flow volumes measured by the treatment plant return flow magmeter. The same as prior reports, the area-velocity meter and magmeter have recorded similar volumes that are within normal levels of instrumentation and measurement error (refer to Appendix C for 2024 quarterly reports). Consequently, the redundant meters have been discontinued (January 2025) and equipment will be removed in 2025. This will require temporarily pausing return flow so the equipment can be safely removed from the pipe.

E. Consumptive Use

Requirement: The total consumptive use as defined in Wis. Stat. §281.346(1)(e).

In 2024, the WWU had 12 customers who measured consumptive use or water volume used during production. The total water usage associated with production was 34,381,500 gallons.

When the City began the Lake Michigan diversion, the WDNR requested that consumptive use be calculated using both the winter-based rate (WBR) method and a separate calculation that includes the water loss reported to the Wisconsin Public Service Commission (WPSC) and water used by industry that is incorporated into food and beverage products.

The WBR method primarily focuses on outdoor water use (lawn and landscape watering, car washing, pools) and assumes most of the consumptive use in municipal water supply systems is from evapotranspiration. Given that the City's water use peaks in summer months, the WDNR accepts this method to calculate domestic consumptive use. Annual and summer consumptive use are calculated as follows:

- The WBR method calculates annual consumptive use according to the following equation:

  Annual consumptive-use coefficient (%) = [(Sum of all monthly withdrawals ÷ 12) – (Sum of winter-month withdrawals ÷ 3)] ÷ (Sum of all monthly withdrawals ÷ 12) × 100

  Note: "All months" are January through December and "winter months" are January, February, and December.

- The WBR method calculates summer consumptive use according to the following equation:

  Summer consumptive-use coefficient (%) = [(Sum of summer monthly withdrawals – Sum of winter monthly withdrawals) ÷ Sum of summer monthly withdrawals] × 100

  Note: "Summer months" are June, July, and August. This basic equation also is used to estimate coefficients for spring (March, April, and May) and fall (September, October, and November).

The annual and summer consumptive-use coefficient calculations following the WBR method are summarized in Table E-1. The City's annual coefficient and summer coefficient are both much lower than that calculated by the USGS for other midwestern states (2.9% compared to 6% to 8%, and 8.2% compared to 16% to 20%, respectively)[1].

[1] Shaffer, K.H. 2009. *Variations in Withdrawal, Return Flow, and Consumptive Use of Water in Ohio and Indiana, with Selected Data from Wisconsin, 1999–2004*. U.S. Geological Survey Scientific Investigations Report 2009–5096, 93 p. "The public-supply annual average consumptive-use coefficient calculated by use of the WBR method ranged from 6 to 8 percent, and the summer consumptive-use coefficient ranged from 16 to 20 percent for Ohio, Indiana, and Wisconsin." Pg. 65.

Table E-1. 2024 Consumptive-Use Coefficients Following the WBR Method

Total Annual Withdrawal	1,844,782,000	gallons from Lake Michigan
Sum of Winter Withdrawals	447,838,200	gallons from Lake Michigan (Jan, Feb, and Dec 2024)
Sum of Spring Withdrawals	447,456,700	gallons from Lake Michigan (Mar, Apr, and May 2024)
Sum of Summer Withdrawals	487,667,800	gallons from Lake Michigan (Jun, Jul, and Aug 2024)
Sum of Fall Withdrawals	461,819,300	gallons from Lake Michigan (Sep, Oct, and Nov 2024)
Sum of Winter Pumpage	447,838,200	gallons
% Annual Consumptive-use Coefficient	2.9	using Lake Michigan
Sum of Summer Pumpage	487,667,800	gallons
% Summer Consumptive-use Coefficient	8.2	using Lake Michigan

However, calculating consumptive use, including any industry that uses water (food processing, beverage processing), and distribution system losses reported to the WPSC, including water main breaks, service leaks, or faulty pressure valves, results in greater consumptive use. Calculating the consumptive use, including the WBR method, water loss (WPSC), and water used by industry in food and beverage products, yields a 2024 consumptive use of 286,897,001 gallons or 15.6% (Table E-2).

Table E-2. 2024 Total Calculated Consumptive Use

% Annual Consumptive-use Coefficient	2.9	
Total Pumpage	1,844,782,000	gallons of Lake Michigan water
Water Loss (WPSC)	199,086,301	gallons
Water Used by Industry	34,381,500	gallon
Total Consumptive Use	286,897,001	gallons
	15.6%	

The 2024 consumptive-use coefficient for Lake Michigan water is calculated with the following equation:

> Lake Michigan Annual Consumptive-Use Coefficient (%) = [(Total Water Purchased from City of Milwaukee) – (Total Wastewater Return to Root River)] ÷ (Total Water Purchased from City of Milwaukee) x 100

The City returned slightly more water to the Root River than was purchased from MWW during 2024, resulting in a negative consumptive-use coefficient for Lake Michigan water supply of -5.4%.

F. Water Conservation and Efficiency Plan

Requirement: A summary of the impact of the implemented Conservation and Efficiency Measures required under Wis. Admin. Code §§ NR 852.04 and NR 852.05, including quantifiable impacts to water use intensity, as defined in Wis. Admin. Code § NR 852.03(29). Water use intensity metric calculation methods as specified by the WDNR.

The City's 2024 conservation and efficiency measures (CEMs) are summarized in Table F-1.

Table F-1. 2024 Conservation and Efficiency Measures

Required CEM	2023 Activity
PWS – 1, Water Use Audit	Water loss is 11%.
PWS – 2, Leak Detection and Repair Program	Replaced 17,056 linear feet of mains. Inspected 1,318 hydrants and repaired leaks.
PWS – 3, Information and Education Outreach	Continued education programs and partnerships. This includes WWU's website, newsletters, bill stuffers, and bill messages (WWU and City of Waukesha), newspaper articles, public service announcements, social media, brochures, advertisement content for City Park & Recreation Department Activity Guide, public outreach, community meetings, school programs, street signs (sprinkler ordinance requirements), yard signs (Brown Lawn Campaign), giveaways, and customer water-use audits and leak alerts.
PWS – 4, Source Measurement	All source water is metered and measured.
PWS – R1, Distribution System Pressure Management	The WWU manages system pressures in 10 pressure zones.
PWS – R2, Residential Demand Management Program	In 2024, 59 toilet rebates were issued, 3 showerhead rebates were issued, and 12 rain barrel rebates were issued. A sprinkling ordinance (for all customer classes) was enacted in 2006. Customers are allowed to irrigate twice a week. Street signs and annual mailers provide information on the sprinkling ordinance. Fines are also in place; 1 violator was reported in 2024. An irrigation ordinance (for all customer classes) was adopted in 2015 requiring permits for landscape irrigation systems to ensure irrigation systems are efficient; 2 permits were issued in 2024. Audit program (for residential and non-residential customers) determines high water consumption and sends a postcard to customers who may have a leak. In 2024, 14 residential water audits were conducted and 91 data logging reports were administered to evaluate for water leaks.
PWS – R3, Commercial and Industrial Demand Management Program	In 2024, 0 multi-family showerhead rebates were issued, 7 commercial toilet rebates were issued, and 2 multi-family toilet rebates were issued. In 2024, the utility followed up on a large multi-family account that applied for a toilet changeout in 2024. The utility began the pre-inspection process, but the manager who applied for the toilet rebate quit working at the multi-family facility. A second manager was hired and quit, and now a third manager has been hired. With this transition in management, the multi-family facility had put the toilet changeouts on hold. There were 2 industrial users who participated in the site-specific grant program and completed their projects; however, $0 dollars were given out due to there being no water savings. Zero spray rinse valves were issued. The WWU also has an audit program (for residential and non-residential customers). In 2024, 56 data logging reports were conducted for public, commercial, and industrial customers to evaluate water leaks.
PWS – R4, Water Reuse	The WWU is required to return 100% of the previous year daily water demand; therefore, water reuse at a utility scale is not feasible.
Tier 3, Additional CEMs	In 2024, the remaining 25 sewer credit meters were phased out; zero sewer credit meters remain.

PWS = public water system

F.1 Meter Testing

The water production meter at the Oklahoma Pump Station was tested in January 2025. The water meters at the City's booster pump station (BPS) were installed new in the spring/summer of 2023 and will be tested in 2025. Testing of the meters used for billing occurs in-house, based on the timing requirements of the WPSC. In 2024, 380 meters were tested.

F.2 Water Use Intensity Metrics

The 2024 per capita per day water use for residential, 2-family residential, 3-family residential, and multi-family residential customer categories is summarized in Table F-2.

Table F-2. 2024 Calculated Average Day Water Use per Capita

Customer Class	# of Customers	Annual Sales (gallons)
Residential	17,032	697,912,400
Res – 2 Family	1,228	89,778,200
Res – 3 Family	76	6,735,000
Multi-Family	948	340,635,200
Total	19,284	1,135,060,800
	Days in 2024	366
	Population in 2024	70,446
	Residential per customer (gpd)	161
	Residential per capita (gpd)	44
	Total usage per capita (gpd)	64

gpd = gallon(s) per day

The per capita per day water use calculated using a residential equivalent unit (REU) method is summarized in Table F-3.

Table F-3. 2024 Calculated Average Day Water Use per Residential Equivalent Unit

Meter Size (inches)	Number of Meters	REU Ratio[a]	REU
5/8	18,134	1	18,134
3/4	1,781	1	1,781
1	909	2.5	2,272.5
1 1/4	-	3.7	-
1 1/2	387	5	1,935
2	369	8	2,952
2 1/2	-	12.5	-
3	54	15	810
4	17	25	425
6	10	50	500

Meter Size (inches)	Number of Meters	REU Ratio[a]	REU
8	-	80	-
10	-	122	-
12	-	160	-
Total	21,661	-	28,809.5

[a] From Wisconsin Public Service Commission

Average Day Residential Water Use per REU Calculation

Total Residential Water Sales	1,135,060,800	gallons
Average Day Residential Water Use	3,101,259	gpd
Average Day Residential Water Use/REU	108	gpd/REU

F.3 Water Volume Differences

There is a difference between the daily volume of water purchased from MWW and the volume that enters the WWU distribution system based on the presence of the onsite storage at the BPS. This is evident by comparing pumpage (purchased from MWW) and demand volumes:

- The maximum daily pumpage from MWW was 7,783,900 and occurred on September 6, 2024. This high pumpage day was associated with the flushing of two distribution system reservoirs (not at the BPS) for water quality reasons. The average daily pumpage from MWW was 5,040,388 gallons. This resulted in a ratio of maximum daily pumpage to average daily pumpage of 1.54.
- The maximum daily demand in the WWU distribution system was 6,503,000 gallons, which occurred on September 19, 2024; and is attributed to a week of temperatures that were greater than 80 degrees Fahrenheit (°F), with that specific day being 86°F. The average daily demand in the WWU distribution system was 5,084,439 gallons. This resulted in a ratio of maximum daily demand to average daily demand of 1.28.

The difference between the pumpage and demand volumes is relatively minor; however, different sections within WDNR may use the different volumes. For example, the water use and water supply section will likely use water demand volumes, whereas sections regulating with the Diversion Approval and return flow will likely use pumpage volumes.

G. Additional Conservation and Efficiency Measures

Requirement: A description of any additional Conservation and Efficiency Measures implemented.

Starting in 2006, the WWU implemented a variety of conservation programs. The WWU approved a conservation plan in 2012 that was updated in 2022. An analysis of water savings achieved since the 2012 plan was implemented demonstrates that, by 2021, the WWU has exceeded savings goals established for 2030 and 2050. The near-term program goals (years 1 to 5) were included as Table 5.3 of the 2022 report. Future reporting will include status updates of any new or additional measures implemented from the updated report.

In 2024, WWU began planning a water softener discontinuation program with the CWP (this was based on WWU transitioning to Great Lakes water in 2023, and the Great Lakes water being 60% softer). The water softener discontinuation program is expected to result in not only substantial water-use savings, but also improvements to effluent discharge water quality. On December 28, 2024, a press release informed the public that a water softener removal rebate program will begin in January 2025.

In 2024, WWU also began planning a website redesign to make the website more user friendly. This included updating the Conservation & Education section, where more detailed information was added to expand resources to better serve customers. Some of the additions included high water usage information; expanding the Finding and Fixing Leaks section with how to check the leak indicator on the water meter; how to check your toilet for leaks; and how to fix toilets, faucets, showerheads, and outdoor leaks. Information was added to the Incentives & Rebates section – including information on the new water softener rebate program and what the WaterSense label means. Information also was added to the Water Education and Outreach Programs section – including a water footprint calculator and educational resources for teachers and students. The new website was launched on December 2, 2024, with a press release announcing the website's new look.

H. Customers within Diversion Area

Requirement: A statement verifying that no customers outside of the diversion area were sold Lake Michigan water.

The WWU certifies no customers outside of the approved diversion area were sold Lake Michigan water in 2024.

I. Properties Served by Water Utility

Requirement: A spatially explicit description of the properties served by the City's water utility, in the manner prescribed by the DNR.

A map showing the area served by the WWU is included in Appendix D. An electronic geographic information system layer also will accompany this annual report submittal to the WDNR.

J. Existing Deep Aquifer Groundwater Wells

Requirement: A report of any City wells filled and sealed or changed to emergency use status in the past year. A description of deep aquifer groundwater wells maintained for emergency use, as allowed under Wis. Admin. Code § NR 810.22, and use of these wells in the previous year.

A copy of the November 2023 WDNR approval of extended well abandonment agreement for the utility wells is included in Appendix E.

K. Pharmaceutical and Personal Care Products Recycling and Reduction Program

Requirement: A summary of the implementation of the pharmaceutical and personal care products recycling and reduction program in the past year.

Refer to Appendix F.

L. Root River Monitoring

Requirement: For at least 10 years after the date the diversion begins, the City shall annually report the results of Root River monitoring to DNR. The report shall include a summary of the monitoring results and a summary of any impacts to the Root River from the City's wastewater discharge.

Refer to Appendix G.

M. Federal and State Permits and Approvals

Requirement: A statement of compliance with all applicable federal and state permits and approvals.

The City of Waukesha has complied with all applicable federal and state approvals.

N. Summary

Table N-1 is an executive summary of information provided previously.

Table N-1. Summary Table for Reporting Year 2024

Total Water Supply Pumpage from Lake Michigan	1,844,782,000	gallons
Total Water Sold	1,648,585,700	gallons
Population Served	70,446	people
Total per Capita Water Use per Day	64	gpd
Residential per Capita Water Use per Day	44	gpd
Maximum Day Water Pumpage	7,783,900	gallons
Average Day Water Pumpage	5,040,388	gallons
Ratio of Maximum Day Water Pumpage to Average Day Pumpage	1.54	
Average Day Water Pumpage per Residential Equivalency Unit	108	gpd/REU
Average Daily Demand to be Returned to the Root River in 2024	5.26	million gallons per day
Total Clean Water Plant Discharge	3,399,137,000	gallons
Total Clean Water Plant Discharge to the Fox River	1,455,627,000	gallons
Total Clean Water Plant Discharge to the Root River	1,943,510,000	gallons
Total Consumptive Use (WBR + loss + industry)	15.6%	

Appendix A. 2024 Daily Water Supply Volumes from Milwaukee Waterworks

APPENDIX A. 2024 DAILY WATER SUPPLY VOLUMES FROM MILWAUKEE WATERWORKS

Date	Emergency Groundwater Supply (gallons)	Milwaukee Waterworks Supply (gallons)
1/1/2024	0	5,062,400
1/2/2024	0	5,246,500
1/3/2024	0	4,864,900
1/4/2024	0	5,260,300
1/5/2024	0	4,554,800
1/6/2024	0	3,810,100
1/7/2024	0	3,303,700
1/8/2024	0	5,402,500
1/9/2024	0	5,413,800
1/10/2024	0	5,040,700
1/11/2024	0	4,631,500
1/12/2024	0	4,085,500
1/13/2024	0	5,435,900
1/14/2024	0	3,522,800
1/15/2024	0	6,250,900
1/16/2024	0	2,843,300
1/17/2024	0	5,636,200
1/18/2024	0	4,057,600
1/19/2024	0	5,654,100
1/20/2024	0	5,287,200
1/21/2024	0	4,546,600
1/22/2024	0	5,486,200
1/23/2024	0	5,159,800
1/24/2024	0	4,966,700
1/25/2024	0	5,873,600
1/26/2024	0	4,790,700
1/27/2024	0	5,179,000
1/28/2024	0	4,725,200
1/29/2024	0	4,555,000
1/30/2024	0	6,851,200
1/31/2024	0	5,258,700
2/1/2024	0	4,965,800
2/2/2024	0	4,140,600
2/3/2024	0	5,151,700
2/4/2024	0	5,574,600

Date	Emergency Groundwater Supply (gallons)	Milwaukee Waterworks Supply (gallons)
2/5/2024	0	6,196,100
2/6/2024	0	3,930,500
2/7/2024	0	4,619,200
2/8/2024	0	5,327,600
2/9/2024	0	6,710,200
2/10/2024	0	4,887,700
2/11/2024	0	3,486,300
2/12/2024	0	6,350,400
2/13/2024	0	4,474,200
2/14/2024	0	2,937,400
2/15/2024	0	5,086,100
2/16/2024	0	5,325,200
2/17/2024	0	6,178,200
2/18/2024	0	4,842,500
2/19/2024	0	5,600,300
2/20/2024	0	3,976,400
2/21/2024	0	6,632,000
2/22/2024	0	5,234,700
2/23/2024	0	3,774,000
2/24/2024	0	4,924,500
2/25/2024	0	5,034,200
2/26/2024	0	3,465,100
2/27/2024	0	7,249,700
2/28/2024	0	4,434,200
2/29/2024	0	5,660,500
3/1/2024	0	4,713,200
3/2/2024	0	4,630,300
3/3/2024	0	4,870,600
3/4/2024	0	6,090,600
3/5/2024	0	2,500,300
3/6/2024	0	6,450,700
3/7/2024	0	5,128,200
3/8/2024	0	5,467,700
3/9/2024	0	3,802,100
3/10/2024	0	5,018,000

Date	Emergency Groundwater Supply (gallons)	Milwaukee Waterworks Supply (gallons)
3/11/2024	0	5,759,400
3/12/2024	0	4,476,900
3/13/2024	0	3,914,900
3/14/2024	0	5,987,500
3/15/2024	0	3,568,700
3/16/2024	0	4,583,000
3/17/2024	0	5,200,800
3/18/2024	0	4,585,300
3/19/2024	0	4,775,600
3/20/2024	0	5,624,800
3/21/2024	0	4,390,600
3/22/2024	0	5,271,100
3/23/2024	0	3,431,600
3/24/2024	0	6,377,000
3/25/2024	0	4,594,800
3/26/2024	0	4,285,200
3/27/2024	0	4,449,900
3/28/2024	0	4,900,300
3/29/2024	0	6,050,700
3/30/2024	0	3,652,700
3/31/2024	0	4,132,200
4/1/2024	0	5,116,500
4/2/2024	0	3,547,100
4/3/2024	0	5,737,000
4/4/2024	0	5,209,700
4/5/2024	0	4,751,600
4/6/2024	0	4,531,200
4/7/2024	0	4,522,900
4/8/2024	0	4,659,200
4/9/2024	0	5,225,800
4/10/2024	0	3,299,800
4/11/2024	0	5,913,100
4/12/2024	0	4,079,300
4/13/2024	0	4,849,200
4/14/2024	0	3,200,200
4/15/2024	0	6,590,700
4/16/2024	0	5,642,600
4/17/2024	0	5,030,400

Date	Emergency Groundwater Supply (gallons)	Milwaukee Waterworks Supply (gallons)
4/18/2024	0	4,434,100
4/19/2024	0	4,199,700
4/20/2024	0	5,719,000
4/21/2024	0	3,856,300
4/22/2024	0	5,008,500
4/23/2024	0	5,893,200
4/24/2024	0	5,110,200
4/25/2024	0	4,352,900
4/26/2024	0	5,471,800
4/27/2024	0	4,372,500
4/28/2024	0	4,276,400
4/29/2024	0	4,658,800
4/30/2024	0	5,362,900
5/1/2024	0	4,912,600
5/2/2024	0	5,728,100
5/3/2024	0	4,770,800
5/4/2024	0	4,639,700
5/5/2024	0	4,087,600
5/6/2024	0	6,624,600
5/7/2024	0	4,180,500
5/8/2024	0	5,475,700
5/9/2024	0	4,309,400
5/10/2024	0	4,788,100
5/11/2024	0	5,075,200
5/12/2024	0	5,359,600
5/13/2024	0	3,029,100
5/14/2024	0	5,487,600
5/15/2024	0	5,134,700
5/16/2024	0	6,184,500
5/17/2024	0	4,222,600
5/18/2024	0	5,522,200
5/19/2024	0	5,365,200
5/20/2024	0	5,037,000
5/21/2024	0	6,100,500
5/22/2024	0	4,469,100
5/23/2024	0	6,091,000
5/24/2024	0	5,534,700
5/25/2024	0	3,554,700

Date	Emergency Groundwater Supply (gallons)	Milwaukee Waterworks Supply (gallons)
5/26/2024	0	4,336,400
5/27/2024	0	5,906,400
5/28/2024	0	5,075,700
5/29/2024	0	3,843,700
5/30/2024	0	4,209,500
5/31/2024	0	5,092,900
6/1/2024	0	5,558,900
6/2/2024	0	4,510,000
6/3/2024	0	6,322,900
6/4/2024	0	5,234,800
6/5/2024	0	4,727,100
6/6/2024	0	5,263,900
6/7/2024	0	4,252,400
6/8/2024	0	5,461,900
6/9/2024	0	4,486,700
6/10/2024	0	3,799,900
6/11/2024	0	6,051,800
6/12/2024	0	5,973,400
6/13/2024	0	5,069,900
6/14/2024	0	6,075,400
6/15/2024	0	4,923,000
6/16/2024	0	5,380,200
6/17/2024	0	6,125,500
6/18/2024	0	4,115,500
6/19/2024	0	6,613,900
6/20/2024	0	5,253,600
6/21/2024	0	4,913,000
6/22/2024	0	6,302,700
6/23/2024	0	3,701,400
6/24/2024	0	5,435,100
6/25/2024	0	4,861,400
6/26/2024	0	5,495,200
6/27/2024	0	6,024,800
6/28/2024	0	5,555,300
6/29/2024	0	3,896,100
6/30/2024	0	6,001,700
7/1/2024	0	5,380,500
7/2/2024	0	4,509,600

Date	Emergency Groundwater Supply (gallons)	Milwaukee Waterworks Supply (gallons)
7/3/2024	0	5,534,400
7/4/2024	0	5,241,400
7/5/2024	0	4,653,500
7/6/2024	0	4,261,400
7/7/2024	0	3,533,400
7/8/2024	0	5,216,900
7/9/2024	0	4,882,300
7/10/2024	0	5,313,300
7/11/2024	0	5,650,100
7/12/2024	0	7,776,200
7/13/2024	0	4,806,300
7/14/2024	0	7,019,700
7/15/2024	0	5,440,100
7/16/2024	0	5,672,600
7/17/2024	0	5,639,200
7/18/2024	0	5,359,100
7/19/2024	0	4,093,700
7/20/2024	0	5,398,400
7/21/2024	0	4,444,900
7/22/2024	0	4,431,300
7/23/2024	0	5,129,700
7/24/2024	0	6,861,700
7/25/2024	0	6,159,900
7/26/2024	0	4,699,600
7/27/2024	0	5,475,900
7/28/2024	0	5,684,200
7/29/2024	0	4,578,500
7/30/2024	0	4,819,400
7/31/2024	0	5,245,500
8/1/2024	0	5,528,800
8/2/2024	0	5,141,100
8/3/2024	0	4,917,000
8/4/2024	0	5,449,800
8/5/2024	0	5,119,900
8/6/2024	0	6,043,900
8/7/2024	0	5,177,000
8/8/2024	0	5,048,700
8/9/2024	0	5,559,500

Date	Emergency Groundwater Supply (gallons)	Milwaukee Waterworks Supply (gallons)
8/10/2024	0	5,047,700
8/11/2024	0	5,603,300
8/12/2024	0	4,106,000
8/13/2024	0	6,188,100
8/14/2024	0	5,429,700
8/15/2024	0	6,031,200
8/16/2024	0	4,544,800
8/17/2024	0	4,644,800
8/18/2024	0	4,181,900
8/19/2024	0	5,636,500
8/20/2024	0	5,982,800
8/21/2024	0	5,414,100
8/22/2024	0	5,380,200
8/23/2024	0	6,104,400
8/24/2024	0	4,948,800
8/25/2024	0	5,369,700
8/26/2024	0	5,755,700
8/27/2024	0	5,964,200
8/28/2024	0	6,523,800
8/29/2024	0	5,085,800
8/30/2024	0	6,481,500
8/31/2024	0	4,957,000
9/1/2024	0	4,732,900
9/2/2024	0	4,584,600
9/3/2024	0	6,034,300
9/4/2024	0	4,877,300
9/5/2024	0	5,156,000
9/6/2024	0	7,783,900
9/7/2024	0	5,099,000
9/8/2024	0	4,901,000
9/9/2024	0	4,642,300
9/10/2024	0	5,667,300
9/11/2024	0	6,728,500
9/12/2024	0	5,901,300
9/13/2024	0	5,970,600
9/14/2024	0	5,658,700
9/15/2024	0	5,644,100
9/16/2024	0	5,383,900

Date	Emergency Groundwater Supply (gallons)	Milwaukee Waterworks Supply (gallons)
9/17/2024	0	5,950,700
9/18/2024	0	5,912,300
9/19/2024	0	6,427,100
9/20/2024	0	6,103,500
9/21/2024	0	5,474,300
9/22/2024	0	4,035,300
9/23/2024	0	5,238,700
9/24/2024	0	4,282,200
9/25/2024	0	4,899,500
9/26/2024	0	6,303,600
9/27/2024	0	4,681,100
9/28/2024	0	5,314,000
9/29/2024	0	5,400,800
9/30/2024	0	4,376,100
10/1/2024	0	4,887,800
10/2/2024	0	5,111,100
10/3/2024	0	5,476,100
10/4/2024	0	5,639,600
10/5/2024	0	5,307,200
10/6/2024	0	5,052,900
10/7/2024	0	5,005,400
10/8/2024	0	5,451,600
10/9/2024	0	4,838,200
10/10/2024	0	5,265,200
10/11/2024	0	5,731,400
10/12/2024	0	3,167,200
10/13/2024	0	5,231,500
10/14/2024	0	4,300,800
10/15/2024	0	5,205,200
10/16/2024	0	6,269,200
10/17/2024	0	6,002,600
10/18/2024	0	4,974,500
10/19/2024	0	4,888,300
10/20/2024	0	4,543,800
10/21/2024	0	4,458,000
10/22/2024	0	4,373,300
10/23/2024	0	5,423,900
10/24/2024	0	5,273,100

Date	Emergency Groundwater Supply (gallons)	Milwaukee Waterworks Supply (gallons)
10/25/2024	0	4,303,600
10/26/2024	0	6,034,100
10/27/2024	0	4,430,300
10/28/2024	0	5,471,300
10/29/2024	0	3,970,800
10/30/2024	0	5,453,800
10/31/2024	0	3,869,300
11/1/2024	0	5,562,900
11/2/2024	0	5,093,700
11/3/2024	0	4,797,400
11/4/2024	0	4,825,500
11/5/2024	0	4,438,300
11/6/2024	0	4,439,300
11/7/2024	0	4,106,200
11/8/2024	0	5,551,100
11/9/2024	0	5,346,200
11/10/2024	0	4,262,400
11/11/2024	0	4,267,300
11/12/2024	0	4,666,500
11/13/2024	0	4,647,500
11/14/2024	0	5,852,100
11/15/2024	0	5,062,100
11/16/2024	0	4,429,600
11/17/2024	0	4,744,900
11/18/2024	0	4,293,100
11/19/2024	0	4,344,300
11/20/2024	0	4,904,100
11/21/2024	0	4,294,000
11/22/2024	0	5,384,900
11/23/2024	0	4,968,100
11/24/2024	0	4,460,100
11/25/2024	0	5,118,700
11/26/2024	0	4,832,100
11/27/2024	0	5,163,700
11/28/2024	0	5,141,700
11/29/2024	0	3,862,000
11/30/2024	0	4,383,500
12/1/2024	0	4,718,600

Date	Emergency Groundwater Supply (gallons)	Milwaukee Waterworks Supply (gallons)
12/2/2024	0	4,722,100
12/3/2024	0	5,620,500
12/4/2024	0	4,846,000
12/5/2024	0	5,856,100
12/6/2024	0	4,625,000
12/7/2024	0	4,468,200
12/8/2024	0	3,952,000
12/9/2024	0	5,573,700
12/10/2024	0	6,402,500
12/11/2024	0	4,833,900
12/12/2024	0	5,356,100
12/13/2024	0	4,713,700
12/14/2024	0	5,077,600
12/15/2024	0	4,204,300
12/16/2024	0	5,278,100
12/17/2024	0	4,414,300
12/18/2024	0	4,168,200
12/19/2024	0	4,671,700
12/20/2024	0	5,268,400
12/21/2024	0	5,422,100
12/22/2024	0	5,163,400
12/23/2024	0	3,924,600
12/24/2024	0	4,228,900
12/25/2024	0	3,658,900
12/26/2024	0	5,132,000
12/27/2024	0	4,232,200
12/28/2024	0	4,193,200
12/29/2024	0	5,527,500
12/30/2024	0	4,907,900
12/31/2024	0	3,749,200

Appendix B. 2024 Daily Clean Water Plant Discharge Volumes to the Root and Fox Rivers

APPENDIX B. 2024 DAILY CLEAN WATER PLANT DISCHARGE VOLUMES TO THE ROOT AND FOX RIVERS

Date	Fox River Discharge Volume (gallons)	Root River Discharge Volume (gallons)	Total Clean Water Plant Discharge Volume (gallons)	Comments
1/1/2024	1,972,000	4,750,000	6,722,000	Return flow gate malfunction resulted in pumps shutting down. Alarm did not alert CWP.
1/2/2024	1,514,000	5,310,000	6,824,000	
1/3/2024	2,297,000	4,510,000	6,807,000	Return flow gate limits malfunction in the morning. Manufacturer representative onsite to correct issue.
1/4/2024	1,520,000	5,310,000	6,830,000	
1/5/2024	1,937,000	5,310,000	7,247,000	
1/6/2024	1,399,000	5,310,000	6,709,000	
1/7/2024	1,531,000	5,310,000	6,841,000	
1/8/2024	1,241,000	5,310,000	6,551,000	
1/9/2024	1,678,000	5,310,000	6,988,000	
1/10/2024	1,794,000	5,310,000	7,104,000	
1/11/2024	1,768,000	5,310,000	7,078,000	
1/12/2024	1,823,000	5,310,000	7,133,000	
1/13/2024	1,704,000	5,230,000	6,934,000	Fox River gate malfunctioned causing pumps to not turn on. Manufacturer representative onsite 1/18 to correct.
1/14/2024	1,748,000	5,310,000	7,058,000	
1/15/2024	1,595,000	5,310,000	6,905,000	
1/16/2024	1,604,000	5,310,000	6,914,000	
1/17/2024	1,743,000	5,310,000	7,053,000	
1/18/2024	1,634,000	5,320,000	6,954,000	
1/19/2024	1,521,000	5,310,000	6,831,000	
1/20/2024	1,546,000	5,310,000	6,856,000	
1/21/2024	1,598,000	5,310,000	6,908,000	

Date	Fox River Discharge Volume (gallons)	Root River Discharge Volume (gallons)	Total Clean Water Plant Discharge Volume (gallons)	Comments
1/22/2024	1,581,000	5,310,000	6,891,000	
1/23/2024	1,971,000	5,310,000	7,281,000	
1/24/2024	2,220,000	5,310,000	7,530,000	
1/25/2024	2,486,000	5,310,000	7,796,000	
1/26/2024	3,438,000	5,310,000	8,748,000	
1/27/2024	4,600,000	5,310,000	9,910,000	
1/28/2024	5,236,000	5,310,000	10,546,000	
1/29/2024	5,059,000	5,310,000	10,369,000	
1/30/2024	5,029,000	5,310,000	10,339,000	
1/31/2024	4,733,000	5,310,000	10,043,000	
2/1/2024	5,242,000	5,310,000	10,552,000	
2/2/2024	5,309,000	5,310,000	10,619,000	
2/3/2024	4,925,000	5,310,000	10,235,000	
2/4/2024	4,856,000	5,320,000	10,176,000	
2/5/2024	4,540,000	5,310,000	9,850,000	
2/6/2024	4,182,000	5,310,000	9,492,000	
2/7/2024	4,115,000	5,310,000	9,425,000	
2/8/2024	4,295,000	5,310,000	9,605,000	
2/9/2024	4,368,000	5,310,000	9,678,000	
2/10/2024	3,902,000	5,310,000	9,212,000	
2/11/2024	3,763,000	5,310,000	9,073,000	
2/12/2024	3,604,000	5,310,000	8,914,000	
2/13/2024	3,522,000	5,310,000	8,832,000	
2/14/2024	3,164,000	5,310,000	8,474,000	
2/15/2024	3,641,000	5,310,000	8,951,000	
2/16/2024	3,241,000	5,310,000	8,551,000	

Date	Fox River Discharge Volume (gallons)	Root River Discharge Volume (gallons)	Total Clean Water Plant Discharge Volume (gallons)	Comments
2/17/2024	3,104,000	5,310,000	8,414,000	
2/18/2024	3,178,000	5,310,000	8,488,000	
2/19/2024	2,888,000	5,320,000	8,208,000	
2/20/2024	2,957,000	5,310,000	8,267,000	
2/21/2024	2,865,000	5,310,000	8,175,000	
2/22/2024	2,732,000	5,310,000	8,042,000	
2/23/2024	2,582,000	5,310,000	7,892,000	
2/24/2024	2,544,000	5,310,000	7,854,000	
2/25/2024	2,753,000	5,310,000	8,063,000	
2/26/2024	2,651,000	5,310,000	7,961,000	
2/27/2024	2,664,000	5,310,000	7,974,000	
2/28/2024	2,481,000	5,310,000	7,791,000	
2/29/2024	2,306,000	5,310,000	7,616,000	
3/1/2024	2,392,000	5,310,000	7,702,000	
3/2/2024	2,338,000	5,310,000	7,648,000	
3/3/2024	2,548,000	5,310,000	7,858,000	
3/4/2024	2,440,000	5,310,000	7,750,000	
3/5/2024	3,883,000	5,310,000	9,193,000	
3/6/2024	3,292,000	5,310,000	8,602,000	
3/7/2024	3,225,000	5,310,000	8,535,000	
3/8/2024	3,770,000	5,320,000	9,090,000	
3/9/2024	4,243,000	5,310,000	9,553,000	
3/10/2024	3,793,000	5,310,000	9,103,000	
3/11/2024	3,680,000	5,310,000	8,990,000	
3/12/2024	3,465,000	5,310,000	8,775,000	
3/13/2024	6,140,000	5,310,000	11,450,000	

Date	Fox River Discharge Volume (gallons)	Root River Discharge Volume (gallons)	Total Clean Water Plant Discharge Volume (gallons)	Comments
3/14/2024	6,955,000	5,310,000	12,265,000	
3/15/2024	6,212,000	5,310,000	11,522,000	
3/16/2024	5,596,000	5,310,000	10,906,000	
3/17/2024	5,008,000	5,310,000	10,318,000	
3/18/2024	4,900,000	5,310,000	10,210,000	
3/19/2024	4,359,000	5,310,000	9,669,000	
3/20/2024	4,103,000	5,310,000	9,413,000	
3/21/2024	4,411,000	5,310,000	9,721,000	
3/22/2024	4,029,000	5,310,000	9,339,000	
3/23/2024	4,333,000	5,310,000	9,643,000	
3/24/2024	5,416,000	5,310,000	10,726,000	
3/25/2024	12,011,000	5,310,000	17,321,000	
3/26/2024	9,854,000	5,320,000	15,174,000	
3/27/2024	8,233,000	5,310,000	13,543,000	
3/28/2024	7,141,000	5,310,000	12,451,000	
3/29/2024	7,763,000	5,310,000	13,073,000	
3/30/2024	6,846,000	5,310,000	12,156,000	
3/31/2024	7,102,000	5,310,000	12,412,000	
4/1/2024	12,631,000	5,310,000	17,941,000	
4/2/2024	18,179,000	5,310,000	23,489,000	
4/3/2024	16,058,000	5,310,000	21,368,000	
4/4/2024	13,278,000	5,310,000	18,588,000	
4/5/2024	11,563,000	5,310,000	16,873,000	
4/6/2024	11,186,000	5,310,000	16,496,000	
4/7/2024	10,455,000	5,310,000	15,765,000	
4/8/2024	9,046,000	5,310,000	14,356,000	

Date	Fox River Discharge Volume (gallons)	Root River Discharge Volume (gallons)	Total Clean Water Plant Discharge Volume (gallons)	Comments
4/9/2024	8,282,000	5,310,000	13,592,000	
4/10/2024	7,922,000	5,310,000	13,232,000	
4/11/2024	7,452,000	5,310,000	12,762,000	
4/12/2024	6,730,000	5,310,000	12,040,000	
4/13/2024	6,519,000	5,310,000	11,829,000	
4/14/2024	5,366,000	5,310,000	10,676,000	
4/15/2024	6,234,000	5,320,000	11,554,000	
4/16/2024	6,857,000	5,310,000	12,167,000	
4/17/2024	6,217,000	5,310,000	11,527,000	
4/18/2024	5,925,000	5,310,000	11,235,000	
4/19/2024	5,509,000	5,310,000	10,819,000	
4/20/2024	5,377,000	5,310,000	10,687,000	
4/21/2024	5,536,000	5,310,000	10,846,000	
4/22/2024	5,201,000	5,310,000	10,511,000	
4/23/2024	4,686,000	5,310,000	9,996,000	
4/24/2024	4,060,000	5,310,000	9,370,000	
4/25/2024	4,589,000	5,310,000	9,899,000	
4/26/2024	4,642,000	5,310,000	9,952,000	
4/27/2024	6,014,000	5,310,000	11,324,000	
4/28/2024	5,515,000	5,310,000	10,825,000	
4/29/2024	5,457,000	5,310,000	10,767,000	
4/30/2024	4,844,000	5,320,000	10,164,000	
5/1/2024	4,149,000	5,310,000	9,459,000	
5/2/2024	4,406,000	5,310,000	9,716,000	
5/3/2024	4,676,000	5,310,000	9,986,000	
5/4/2024	4,852,000	5,310,000	10,162,000	

Date	Fox River Discharge Volume (gallons)	Root River Discharge Volume (gallons)	Total Clean Water Plant Discharge Volume (gallons)	Comments
5/5/2024	5,208,000	5,310,000	10,518,000	
5/6/2024	6,701,000	5,310,000	12,011,000	
5/7/2024	7,105,000	5,310,000	12,415,000	
5/8/2024	7,224,000	5,310,000	12,534,000	
5/9/2024	6,422,000	5,310,000	11,732,000	
5/10/2024	5,956,000	5,310,000	11,266,000	
5/11/2024	5,682,000	5,310,000	10,992,000	
5/12/2024	7,073,000	5,310,000	12,383,000	
5/13/2024	5,688,000	5,310,000	10,998,000	
5/14/2024	5,221,000	5,310,000	10,531,000	
5/15/2024	5,322,000	5,310,000	10,632,000	
5/16/2024	4,765,000	5,310,000	10,075,000	
5/17/2024	4,350,000	5,310,000	9,660,000	
5/18/2024	4,324,000	5,310,000	9,634,000	
5/19/2024	5,265,000	5,310,000	10,575,000	
5/20/2024	4,090,000	5,320,000	9,410,000	
5/21/2024	4,959,000	5,310,000	10,269,000	
5/22/2024	4,503,000	5,310,000	9,813,000	
5/23/2024	5,008,000	5,310,000	10,318,000	
5/24/2024	4,818,000	5,310,000	10,128,000	
5/25/2024	5,013,000	5,310,000	10,323,000	
5/26/2024	5,191,000	5,310,000	10,501,000	
5/27/2024	8,014,000	5,310,000	13,324,000	
5/28/2024	6,035,000	5,310,000	11,345,000	
5/29/2024	5,248,000	5,310,000	10,558,000	
5/30/2024	4,547,000	5,310,000	9,857,000	

Date	Fox River Discharge Volume (gallons)	Root River Discharge Volume (gallons)	Total Clean Water Plant Discharge Volume (gallons)	Comments
5/31/2024	4,746,000	5,310,000	10,056,000	
6/1/2024	4,647,000	5,310,000	9,957,000	
6/2/2024	6,644,000	5,310,000	11,954,000	
6/3/2024	8,860,000	5,310,000	14,170,000	
6/4/2024	14,712,000	5,310,000	20,022,000	
6/5/2024	12,364,000	5,310,000	17,674,000	
6/6/2024	10,206,000	5,310,000	15,516,000	
6/7/2024	9,269,000	5,320,000	14,589,000	
6/8/2024	8,379,000	5,310,000	13,689,000	
6/9/2024	7,345,000	5,310,000	12,655,000	
6/10/2024	6,838,000	5,310,000	12,148,000	
6/11/2024	6,438,000	5,310,000	11,748,000	
6/12/2024	6,134,000	5,310,000	11,444,000	
6/13/2024	5,491,000	5,310,000	10,801,000	
6/14/2024	5,120,000	5,310,000	10,430,000	
6/15/2024	5,873,000	5,310,000	11,183,000	
6/16/2024	5,531,000	5,310,000	10,841,000	
6/17/2024	5,419,000	5,310,000	10,729,000	
6/18/2024	5,004,000	5,310,000	10,314,000	
6/19/2024	4,988,000	5,310,000	10,298,000	
6/20/2024	4,880,000	5,310,000	10,190,000	
6/21/2024	8,114,000	5,310,000	13,424,000	
6/22/2024	8,188,000	5,310,000	13,498,000	
6/23/2024	6,431,000	5,310,000	11,741,000	
6/24/2024	10,141,000	5,310,000	15,451,000	
6/25/2024	8,501,000	5,310,000	13,811,000	

Date	Fox River Discharge Volume (gallons)	Root River Discharge Volume (gallons)	Total Clean Water Plant Discharge Volume (gallons)	Comments
6/26/2024	7,344,000	5,310,000	12,654,000	
6/27/2024	7,456,000	5,320,000	12,776,000	
6/28/2024	12,907,000	5,310,000	18,217,000	
6/29/2024	9,642,000	5,310,000	14,952,000	
6/30/2024	8,939,000	5,310,000	14,249,000	
7/1/2024	8,501,000	5,310,000	13,811,000	
7/2/2024	7,830,000	5,310,000	13,140,000	
7/3/2024	6,751,000	5,310,000	12,061,000	
7/4/2024	6,354,000	5,310,000	11,664,000	
7/5/2024	6,252,000	5,310,000	11,562,000	
7/6/2024	6,169,000	5,310,000	11,479,000	
7/7/2024	7,355,000	5,310,000	12,665,000	
7/8/2024	7,077,000	5,310,000	12,387,000	
7/9/2024	6,465,000	5,310,000	11,775,000	
7/10/2024	5,902,000	5,310,000	11,212,000	
7/11/2024	5,380,000	5,310,000	10,690,000	
7/12/2024	5,312,000	5,310,000	10,622,000	
7/13/2024	6,492,000	5,320,000	11,812,000	
7/14/2024	6,333,000	5,310,000	11,643,000	
7/15/2024	5,813,000	5,310,000	11,123,000	
7/16/2024	5,324,000	5,310,000	10,634,000	
7/17/2024	4,930,000	5,310,000	10,240,000	
7/18/2024	4,697,000	5,310,000	10,007,000	
7/19/2024	4,210,000	5,310,000	9,520,000	
7/20/2024	4,399,000	5,310,000	9,709,000	
7/21/2024	3,960,000	5,310,000	9,270,000	

Date	Fox River Discharge Volume (gallons)	Root River Discharge Volume (gallons)	Total Clean Water Plant Discharge Volume (gallons)	Comments
7/22/2024	4,472,000	5,310,000	9,782,000	
7/23/2024	4,136,000	5,310,000	9,446,000	
7/24/2024	3,832,000	5,310,000	9,142,000	
7/25/2024	3,654,000	5,310,000	8,964,000	
7/26/2024	3,298,000	5,310,000	8,608,000	
7/27/2024	4,561,000	5,310,000	9,871,000	
7/28/2024	4,438,000	5,310,000	9,748,000	
7/29/2024	2,908,000	5,320,000	8,228,000	
7/30/2024	3,918,000	6,630,000	10,548,000	Return flow pumping mode inadvertently switched to "quota + min speed." Switched back next day to "quota."
7/31/2024	4,207,000	5,310,000	9,517,000	
8/1/2024	4,140,000	5,310,000	9,450,000	
8/2/2024	3,457,000	5,310,000	8,767,000	
8/3/2024	3,529,000	5,310,000	8,839,000	
8/4/2024	3,530,000	5,310,000	8,840,000	
8/5/2024	5,323,000	5,310,000	10,633,000	
8/6/2024	4,978,000	5,310,000	10,288,000	
8/7/2024	4,640,000	5,310,000	9,950,000	
8/8/2024	3,881,000	5,310,000	9,191,000	
8/9/2024	3,404,000	5,310,000	8,714,000	
8/10/2024	3,378,000	5,310,000	8,688,000	
8/11/2024	3,528,000	5,310,000	8,838,000	
8/12/2024	3,324,000	5,310,000	8,634,000	
8/13/2024	3,271,000	5,310,000	8,581,000	
8/14/2024	4,064,000	5,310,000	9,374,000	
8/15/2024	3,803,000	5,310,000	9,113,000	

Date	Fox River Discharge Volume (gallons)	Root River Discharge Volume (gallons)	Total Clean Water Plant Discharge Volume (gallons)	Comments
8/16/2024	3,052,000	5,310,000	8,362,000	
8/17/2024	3,644,000	5,310,000	8,954,000	
8/18/2024	3,262,000	5,310,000	8,572,000	
8/19/2024	3,226,000	5,310,000	8,536,000	
8/20/2024	3,101,000	5,310,000	8,411,000	
8/21/2024	2,855,000	5,310,000	8,165,000	
8/22/2024	3,104,000	5,310,000	8,414,000	
8/23/2024	2,655,000	5,310,000	7,965,000	
8/24/2024	2,730,000	5,310,000	8,040,000	
8/25/2024	2,788,000	5,310,000	8,098,000	
8/26/2024	3,160,000	5,310,000	8,470,000	
8/27/2024	2,895,000	5,320,000	8,215,000	
8/28/2024	2,701,000	5,310,000	8,011,000	
8/29/2024	1,793,000	5,310,000	7,103,000	
8/30/2024	2,088,000	5,310,000	7,398,000	
8/31/2024	1,919,000	5,310,000	7,229,000	
9/1/2024	2,701,000	5,310,000	8,011,000	
9/2/2024	2,400,000	5,310,000	7,710,000	
9/3/2024	1,739,000	5,310,000	7,049,000	
9/4/2024	2,357,000	5,310,000	7,667,000	
9/5/2024	2,181,000	5,310,000	7,491,000	
9/6/2024	1,897,000	5,310,000	7,207,000	
9/7/2024	2,120,000	5,310,000	7,430,000	
9/8/2024	2,116,000	5,310,000	7,426,000	
9/9/2024	2,044,000	5,310,000	7,354,000	
9/10/2024	2,622,000	5,310,000	7,932,000	

Date	Fox River Discharge Volume (gallons)	Root River Discharge Volume (gallons)	Total Clean Water Plant Discharge Volume (gallons)	Comments
9/11/2024	2,047,000	5,310,000	7,357,000	
9/12/2024	1,193,000	5,310,000	6,503,000	
9/13/2024	1,775,000	5,310,000	7,085,000	
9/14/2024	1,879,000	5,310,000	7,189,000	
9/15/2024	1,873,000	5,310,000	7,183,000	
9/16/2024	2,534,000	5,310,000	7,844,000	
9/17/2024	1,985,000	5,310,000	7,295,000	
9/18/2024	1,101,000	5,310,000	6,411,000	
9/19/2024	1,805,000	5,310,000	7,115,000	
9/20/2024	1,509,000	5,310,000	6,819,000	
9/21/2024	6,398,000	5,310,000	11,708,000	
9/22/2024	3,816,000	5,310,000	9,126,000	
9/23/2024	3,282,000	5,310,000	8,592,000	
9/24/2024	2,938,000	5,310,000	8,248,000	
9/25/2024	2,585,000	5,310,000	7,895,000	
9/26/2024	2,469,000	5,310,000	7,779,000	
9/27/2024	2,191,000	5,310,000	7,501,000	
9/28/2024	2,264,000	5,310,000	7,574,000	
9/29/2024	2,341,000	5,310,000	7,651,000	
9/30/2024	2,137,000	5,310,000	7,447,000	
10/1/2024	2,028,000	5,320,000	7,348,000	
10/2/2024	1,920,000	5,310,000	7,230,000	
10/3/2024	1,801,000	5,310,000	7,111,000	
10/4/2024	1,801,000	5,310,000	7,111,000	
10/5/2024	1,812,000	5,310,000	7,122,000	
10/6/2024	1,812,000	5,310,000	7,122,000	

Date	Fox River Discharge Volume (gallons)	Root River Discharge Volume (gallons)	Total Clean Water Plant Discharge Volume (gallons)	Comments
10/7/2024	4,957,000	5,310,000	10,267,000	
10/8/2024	2,074,000	5,310,000	7,384,000	
10/9/2024	1,659,000	5,310,000	6,969,000	
10/10/2024	1,620,000	5,310,000	6,930,000	
10/11/2024	1,499,000	5,310,000	6,809,000	
10/12/2024	1,616,000	5,310,000	6,926,000	
10/13/2024	1,608,000	5,310,000	6,918,000	
10/14/2024	1,567,000	5,310,000	6,877,000	
10/15/2024	1,589,000	5,310,000	6,899,000	
10/16/2024	1,512,000	5,310,000	6,822,000	
10/17/2024	1,274,000	5,310,000	6,584,000	
10/18/2024	1,187,000	5,310,000	6,497,000	
10/19/2024	1,271,000	5,310,000	6,581,000	
10/20/2024	1,358,000	5,310,000	6,668,000	
10/21/2024	1,222,000	5,310,000	6,532,000	
10/22/2024	1,235,000	5,310,000	6,545,000	
10/23/2024	1,259,000	5,310,000	6,569,000	
10/24/2024	1,362,000	5,310,000	6,672,000	
10/25/2024	1,032,000	5,310,000	6,342,000	
10/26/2024	1,288,000	5,310,000	6,598,000	
10/27/2024	1,396,000	5,310,000	6,706,000	
10/28/2024	1,509,000	5,310,000	6,819,000	
10/29/2024	1,584,000	5,310,000	6,894,000	
10/30/2024	2,298,000	5,320,000	7,618,000	
10/31/2024	689,000	5,310,000	5,999,000	
11/1/2024	1,183,000	5,310,000	6,493,000	

Date	Fox River Discharge Volume (gallons)	Root River Discharge Volume (gallons)	Total Clean Water Plant Discharge Volume (gallons)	Comments
11/2/2024	1,304,000	5,310,000	6,614,000	
11/3/2024	1,492,000	5,310,000	6,802,000	
11/4/2024	1,745,000	5,310,000	7,055,000	
11/5/2024	1,633,000	5,310,000	6,943,000	
11/6/2024	1,468,000	5,310,000	6,778,000	
11/7/2024	1,224,000	5,310,000	6,534,000	
11/8/2024	1,289,000	5,310,000	6,599,000	
11/9/2024	1,750,000	5,310,000	7,060,000	
11/10/2024	1,520,000	5,310,000	6,830,000	
11/11/2024	1,412,000	5,310,000	6,722,000	
11/12/2024	1,601,000	5,310,000	6,911,000	
11/13/2024	2,114,000	5,310,000	7,424,000	
11/14/2024	1,703,000	5,310,000	7,013,000	
11/15/2024	1,518,000	5,310,000	6,828,000	
11/16/2024	1,575,000	5,310,000	6,885,000	
11/17/2024	2,363,000	5,310,000	7,673,000	
11/18/2024	2,871,000	5,310,000	8,181,000	
11/19/2024	2,348,000	5,310,000	7,658,000	
11/20/2024	2,633,000	5,310,000	7,943,000	
11/21/2024	2,504,000	5,310,000	7,814,000	
11/22/2024	2,233,000	5,310,000	7,543,000	
11/23/2024	2,398,000	5,310,000	7,708,000	
11/24/2024	2,172,000	5,310,000	7,482,000	
11/25/2024	2,054,000	5,310,000	7,364,000	
11/26/2024	2,408,000	5,320,000	7,728,000	
11/27/2024	2,520,000	5,310,000	7,830,000	

Date	Fox River Discharge Volume (gallons)	Root River Discharge Volume (gallons)	Total Clean Water Plant Discharge Volume (gallons)	Comments
11/28/2024	1,426,000	5,310,000	6,736,000	
11/29/2024	1,923,000	5,310,000	7,233,000	
11/30/2024	1,992,000	5,310,000	7,302,000	
12/1/2024	2,628,000	5,310,000	7,938,000	
12/2/2024	2,007,000	5,310,000	7,317,000	
12/3/2024	2,037,000	5,310,000	7,347,000	
12/4/2024	2,018,000	5,310,000	7,328,000	
12/5/2024	2,018,000	5,310,000	7,328,000	
12/6/2024	1,917,000	5,310,000	7,227,000	
12/7/2024	1,643,000	5,310,000	6,953,000	
12/8/2024	1,688,000	5,310,000	6,998,000	
12/9/2024	1,645,000	5,310,000	6,955,000	
12/10/2024	1,489,000	5,310,000	6,799,000	
12/11/2024	1,490,000	5,310,000	6,800,000	
12/12/2024	1,405,000	5,310,000	6,715,000	
12/13/2024	1,410,000	5,310,000	6,720,000	
12/14/2024	1,600,000	5,310,000	6,910,000	
12/15/2024	1,425,000	5,310,000	6,735,000	
12/16/2024	1,418,000	5,310,000	6,728,000	
12/17/2024	1,288,000	5,310,000	6,598,000	
12/18/2024	1,132,000	5,310,000	6,442,000	
12/19/2024	1,108,000	5,310,000	6,418,000	
12/20/2024	1,102,000	5,310,000	6,412,000	
12/21/2024	1,136,000	5,310,000	6,446,000	
12/22/2024	1,214,000	5,310,000	6,524,000	
12/23/2024	1,223,000	5,310,000	6,533,000	

Date	Fox River Discharge Volume (gallons)	Root River Discharge Volume (gallons)	Total Clean Water Plant Discharge Volume (gallons)	Comments
12/24/2024	708,000	5,310,000	6,018,000	
12/25/2024	1,279,000	5,320,000	6,599,000	
12/26/2024	1,405,000	5,310,000	6,715,000	
12/27/2024	1,607,000	5,310,000	6,917,000	
12/28/2024	1,474,000	5,310,000	6,784,000	
12/29/2024	1,550,000	5,310,000	6,860,000	
12/30/2024	1,505,000	5,310,000	6,815,000	
12/31/2024	1,320,000	5,310,000	6,630,000	

Appendix C. 2024 Area-Velocity and Magmeter Comparison

United States Department of the Interior

U.S. GEOLOGICAL SURVEY

Upper Midwest Water Science Center

Minnesota Office
2280 Woodale Drive
Mounds View, MN 55112
763.783.3100

Wisconsin Office
1 Gifford Pinchot Dr
Madison, WI 53726
608.828.9901

Michigan Office
5840 Enterprise Drive
Lansing, MI 48911
517.887.8903

April 11, 2024

Brent Brown
Jacobs Engineering
1610 N. 2nd Street
Suite 201
Milwaukee, WI 53212

RE: Summary comparison between City of Waukesha Clean Water Plant and USGS return flow Monitoring

Dear Brent,

I am pleased to provide a summary of the City of Waukesha return flow monitoring at the facility located on W. Oakwood Rd in Franklin, WI for the period January through March 2024. Daily volumes measured by the USGS are generally within 1% of those measured by the Clean Water Plant maintained by the city of Waukesha. Although USGS volumes are consistently greater than CWP, they are within normal levels of instrumentation and measurement error and can therefore be considered equivalent estimates. Additional detail is provided below for your review. Please do not hesitate to contact me should you have any questions.

Sincerely,

William R Selbig

William Selbig
Research Hydrologist
USGS – Upper Midwest Water Science Center

<u>Waukesha Clean Water Plant Flow Monitoring: JANUARY – MARCH, 2024</u>

Daily volumes measured by the USGS were slightly greater but generally within 1 percent of those measured by the Waukesha Clean Water Plant mag meter (CWP) (figure 1). Differences were greater than 4 percent over a 6-day period in early January (January 3rd – 8th) due to a small leak in the primary bubble line causing erroneous water levels resulting in unreliable USGS computed discharge and volume. Due to the location of the bubble orifice, determination of a correction factor for values measured on January 3rd – 8th was not considered practical because this would have required CWP pumps to be turned off and the facility drained of standing water to gain access. Instead, the secondary area-velocity meter was used to estimate discharge over this time period. The bubble line was repaired on January 9th and percent differences between USGS and CWP daily volumes quickly returned to within 1 percent difference.

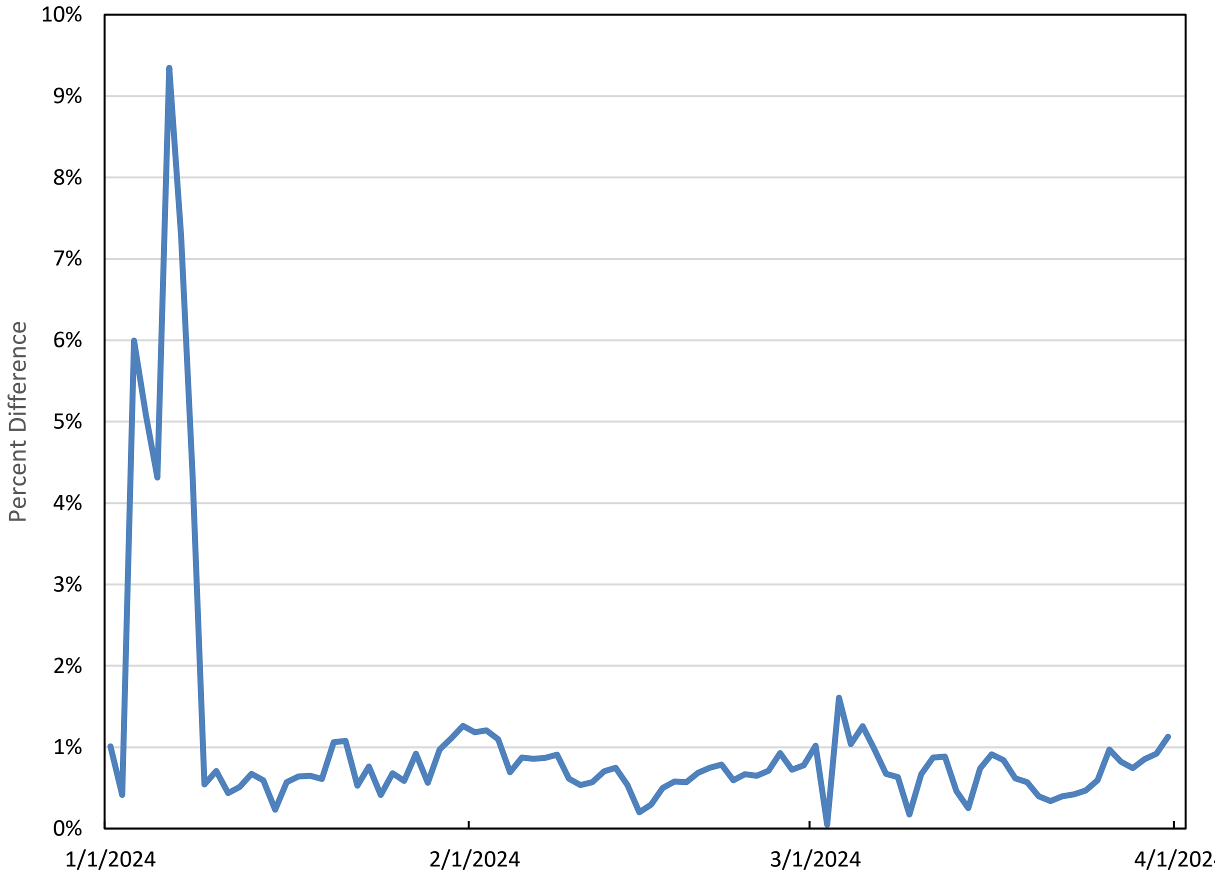


Figure 1. Percent difference between the USGS and CWP daily volume in January through March 2024. A positive value indicates USGS discharge is greater than CWP.

There was little variation in daily volume among and between each month with median values ranging from 710,000 to 715,000 cubic feet and coefficients of variation less than or equal to 0.05 (table 1). Monthly sums were similarly consistent with March having slightly more volume than January and February. February, having two less days than January or March, had the lowest monthly volume. Like daily volumes, differences between monthly sums were generally within 1 percent (table 1). The range of percent differences presented in figure 1 and table 1 is considered acceptable and generally within the accuracy of the meter used to measure discharge at +/- 2 percent.

Table 1. Summary statistics for daily return flow volumes measured by USGS and CWP, January – March 2024. All values rounded to the nearest 1,000 cubic feet unless otherwise noted.

Statistic	JANUARY		FEBRUARY		MARCH	
	USGS	CWP	USGS	CWP	USGS	CWP
Days	31[a]	31	29	29	31	31
Minimum	568,000	599,000	711,000	710,000	709,000	708,000
Maximum	779,000	713,000	719,000	710,000	721,000	713,000
Median	715,000	710,000	715,000	710,000	715,000	710,000
Mean	712,000	703,000	715,000	710,000	715,000	710,000
Standard deviation	38,000	27,000	2,000	28	2,000	1,000
Variation coefficient	0.05	0.04	<0.01	<0.01	<0.01	<0.01
Sum	22,074,000	21,781,000	20,736,000	20,588,000	22,162,000	22,006,000
Sum, % difference	1.3%		0.7%		0.7%	

a – small leak in USGS bubble line affected about 6 days of USGS data

United States Department of the Interior
U.S. GEOLOGICAL SURVEY
Upper Midwest Water Science Center

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Madison, WI 53726
608.828.9901

Michigan Office
5840 Enterprise Drive
Lansing, MI 48911
517.887.8903

July 15, 2024

Brent Brown
Jacobs Engineering
1610 N. 2nd Street
Suite 201
Milwaukee, WI 53212

RE: Summary comparison between City of Waukesha Clean Water Plant and USGS return flow Monitoring

Dear Brent,

I am pleased to provide a summary of the City of Waukesha's return flow monitoring at the facility located on W. Oakwood Rd in Franklin, WI for the period **April through June 2024.** Localized flooding of the Root River in early April created a backwater condition in the return flow discharge pipe that affected estimates of discharge on April 3rd and 4th. Daily volumes measured by the USGS for all other dates were within 1% of those measured by the Clean Water Plant (CWP) maintained by the City of Waukesha. Additional detail is provided below for your review. Please do not hesitate to contact me should you have any questions.

Sincerely,

William R Selbig

William Selbig
Research Hydrologist
USGS – Upper Midwest Water Science Center

Waukesha Clean Water Plant Flow Monitoring: APRIL – JUNE, 2024

Flooding of the Root River in early April created backwater conditions near the City's return flow discharge structure at 60th Street and Oakwood Avenue causing water levels at the USGS monitoring location to erroneously increase (figures 1 and 2). The regression used to compute instantaneous discharge by the USGS assumes free flowing conditions and does not adjust for changes in velocity. This approach to computing discharge was selected to limit the influence of velocity sensors that can be prone to error and are difficult to calibrate. However, during periods of backwater, an increase in water level without correction for reduced velocity will produce erroneous discharge values when using a stage-discharge regression. Therefore, USGS measured discharge and calculated volume were considered unreliable on April 3rd and 4th. They were subsequently censored when comparing to daily CWP mag meter values. USGS measurements of discharge returned to normal after flood waters receded later in the day on April 4th. The backwater conditions did not impact the CWP mag meter flow measurements.

Figure 1. Photo of water levels in the Root R. encroaching upon the return flow discharge structure. Photo taken on April 4, 2024 at 12:40 pm.

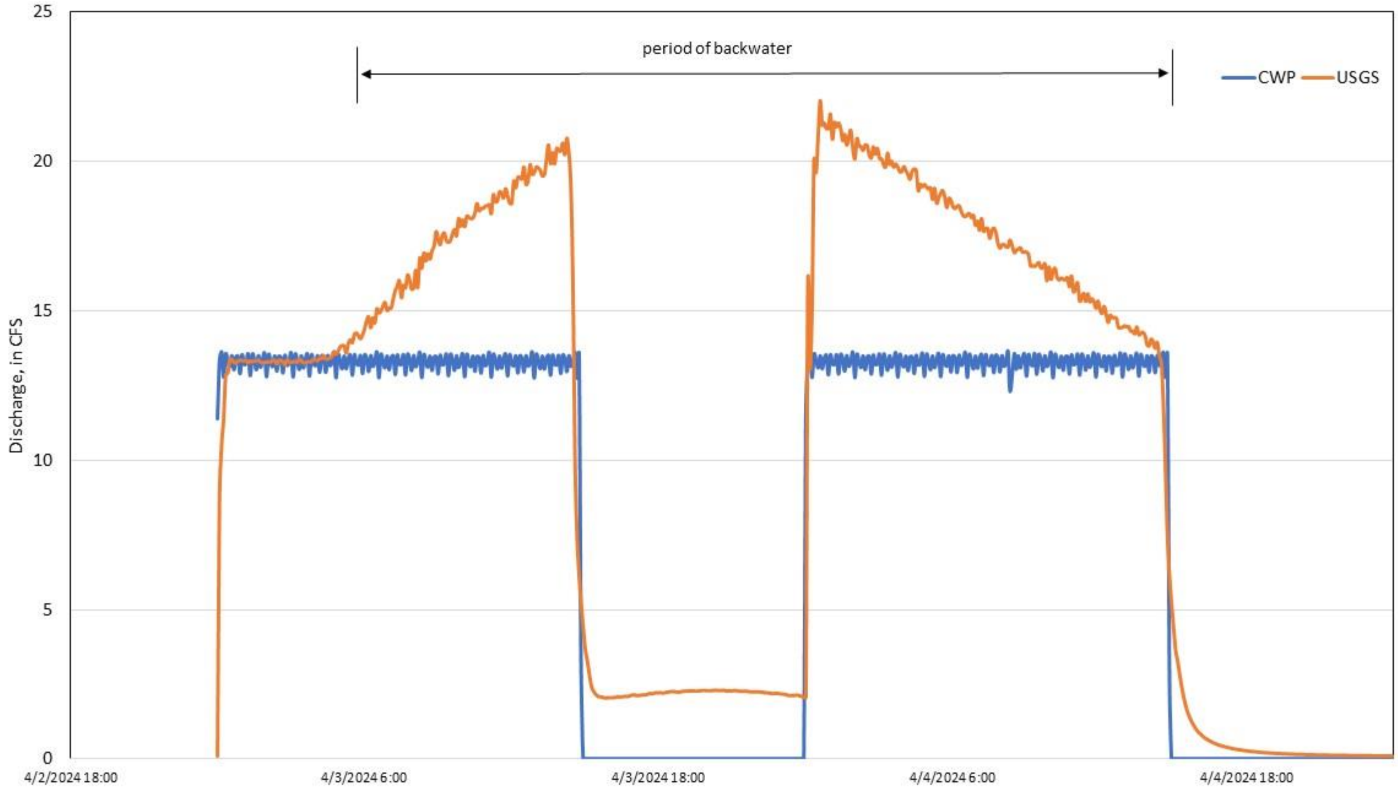

Figure 2. Backwater from the Root R. created erroneous measurements of discharge by USGS on April 3rd and 4th. Note how USGS and CWP measurements were in close agreement prior to the effect of backwater on April 3rd. Measurements returned to normal later in the day on April 4 as flood waters receded.

Except for April 3rd and 4th, daily volumes measured by the USGS were generally within 1 percent of those measured by the CWP mag meter (figure 3). There was little variation in daily volume among and between each month with median values ranging from approximately 710,000 to 717,000 cubic feet and coefficients of variation less than or equal to 0.01 (table 1). Monthly sums were similarly consistent with May having slightly more volume than April and June. April, having two less days than May or June due to the influence of backwater, had the lowest monthly volume. Like daily volumes, differences between monthly sums were within 1 percent (table 1). The range of percent differences presented in figure 3 and table 1 is considered acceptable and within the accuracy of the meter used to measure discharge at +/- 2 percent.

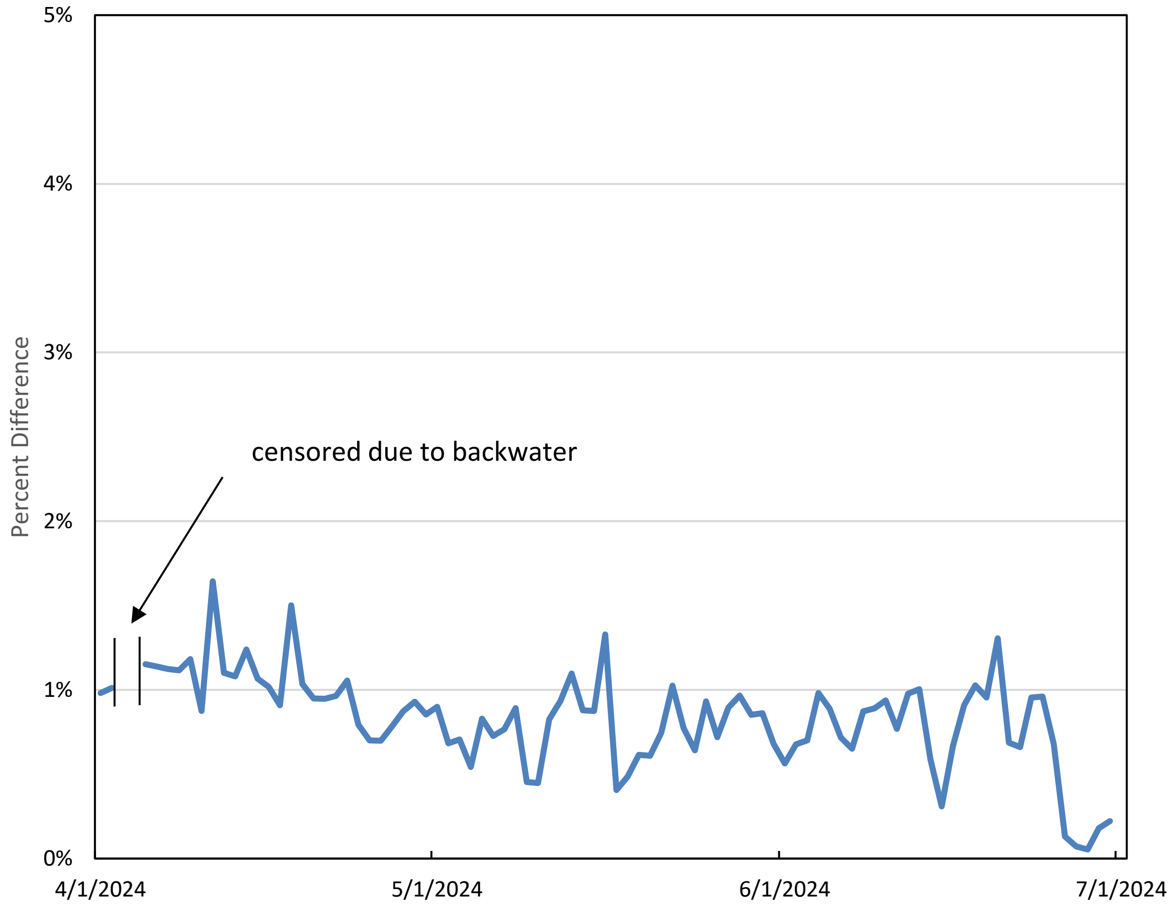

Figure 3. Percent difference between the USGS and CWP daily volume in April through June 2024. A positive value indicates USGS flow measurement is greater than the CWP's measurement. Flooding of the Root R. in early April caused backwater conditions near the CWP making measurements unreliable.

Table 1. Summary statistics for daily return flow volumes measured by USGS and CWP, April – June 2024. All values rounded to the nearest 1,000 cubic feet unless otherwise noted.

Statistic	APRIL		MAY		JUNE	
	USGS	CWP	USGS	CWP	USGS	CWP
Days	28[a]	28[a]	31	31	30	30
Minimum	714,831	705,860	713,129	705,491	709,937	706,819
Maximum	720,651	710,019	717,726	710,403	717,211	710,138
Median	717,144	709,914	715,380	709,908	715,010	709,905
Mean	717,082	709,764	715,325	709,785	714,714	709,726
Standard deviation	1,232	767	1,202	807	2,261	641
Variation coefficient	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sum	20,078,287	19,873,379	22,175,082	22,003,350	21,441,413	21,291,782
Sum, % difference	1.0%		0.8%		0.7%	

a – does not include April 3-4

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Upper Midwest Water Science Center

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Michigan Office
5840 Enterprise Drive
Lansing, MI 48911
517.887.8903

October 7, 2024

Brent Brown
Jacobs Engineering
1610 N. 2nd Street
Suite 201
Milwaukee, WI 53212

RE: Summary comparison between City of Waukesha Clean Water Plant and USGS return flow Monitoring

Dear Brent,

I am pleased to provide a summary of the City of Waukesha's return flow monitoring at the facility located on W. Oakwood Rd in Franklin, WI for the period **July through September 2024.** Daily volumes measured by the USGS were generally within 1% of those measured by the Clean Water Plant (CWP) maintained by the City of Waukesha. Additional detail is provided herein for your review. Please do not hesitate to contact me should you have any questions.

Sincerely,

William R Selbig

William Selbig
Research Hydrologist
USGS – Upper Midwest Water Science Center

Waukesha Clean Water Plant Flow Monitoring: JULY - SEPTEMBER 2024

USGS measured daily volumes were approximately 4% higher than those measured by CWP from July 1 – July 8, 2024. This discrepancy is likely due to stage values that fell outside the range of levels used for calibration on September 12, 2023. Observed discharge on July 1 – 8, 2024 was approximately 17.8 cfs throughout most of the day which corresponded to a stage value of 4.8 feet, approximately 0.20 feet greater than the maximum calibrated stage of approximately 4.6 feet (figure 1). Any stage value greater than 4.6 feet would have a higher degree of uncertainty due to extrapolation of the regression curve beyond the highest calibrated value. Stage values returned to within the calibrated range on July 9th resulting in USGS daily volumes to return to within 1% of CWP daily volumes and remained consistent through the end of the reporting period (figure 2).

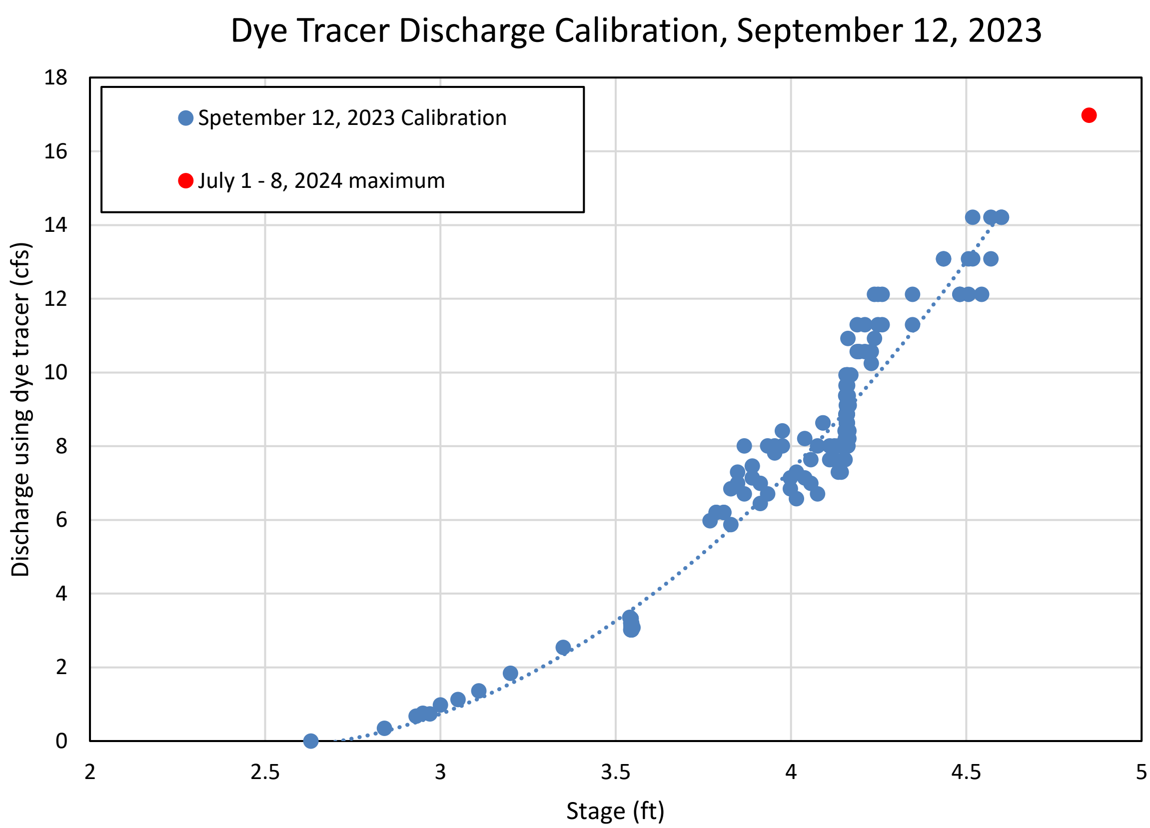

Figure 1. Range of stage values tested during the September 12, 2023 calibration. The maximum stage values measured during the July 1 – 8, 2024 return flow period fell outside this range creating greater uncertainty in discharge value.

There was little variation in daily volume among and between each month with median values ranging from approximately 709,000 to 715,000 cubic feet and coefficients of variation less than or equal to 0.01 (table 1). Monthly sums were similarly consistent with July having slightly more volume than August and September. The return flow discharge from July 1 – 8 was the largest measured discharge since the CWP went online in October 2023. September, having one less day than July or August, had the lowest monthly volume. Like daily volumes, differences between monthly sums were generally within 1 percent (table 1). The range of percent differences presented in figure 2 and table 1 is considered acceptable and within the accuracy of the meter used to measure discharge at +/- 2 percent.

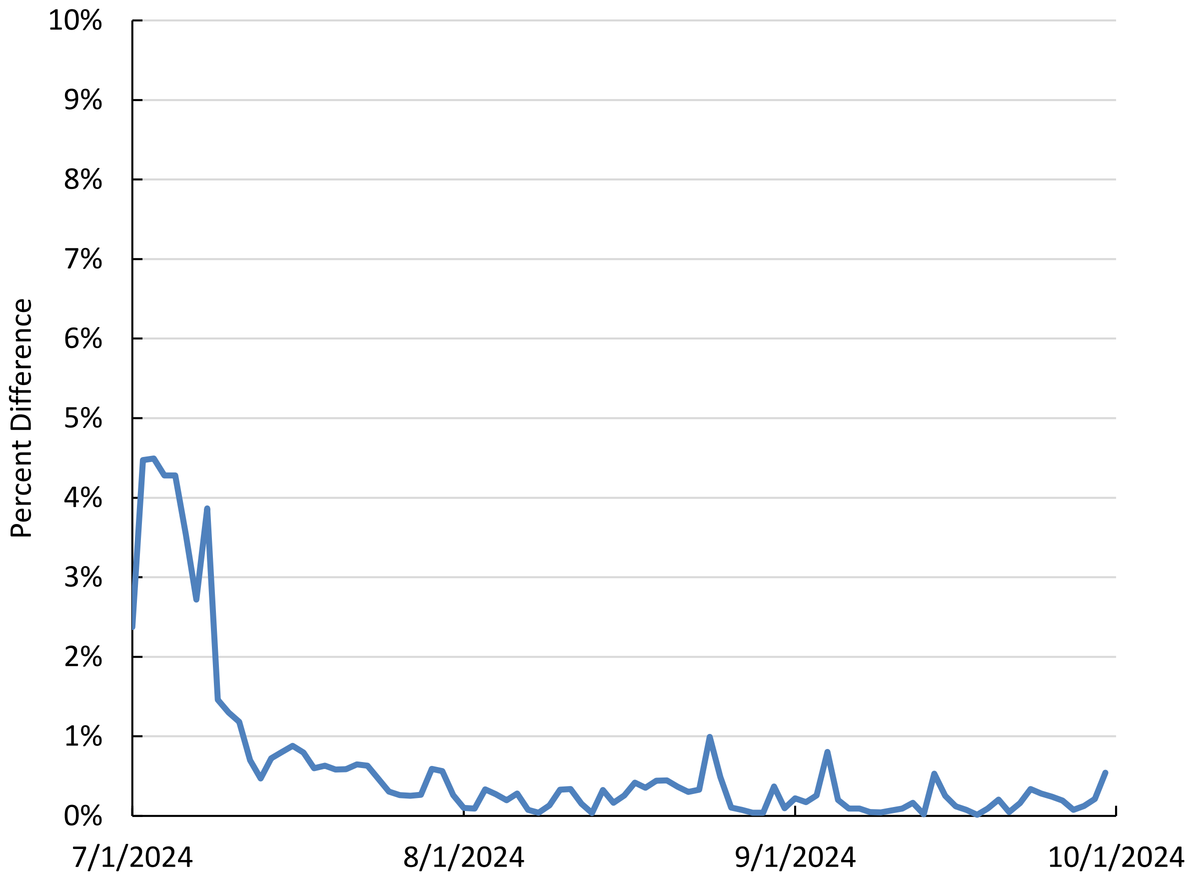

Figure 2. Percent difference between the USGS and CWP daily volume in July through September 2024. A positive value indicates USGS flow measurement is greater than the CWP's measurement.

Table 1. Summary statistics for daily return flow volumes measured by USGS and CWP, July – September 2024. All values rounded to the nearest 1,000 cubic feet unless otherwise noted.

Statistic	JULY		AUGUST		SEPTEMBER	
	USGS	CWP	USGS	CWP	USGS	CWP
Days	31	31	31	31	30	30
Minimum	711,317	709,435	702,918	708,473	707,461	705,863
Maximum	883,413	878,460	712,794	710,999	713,662	711,654
Median	715,370	709,903	708,739	709,889	710,061	709,869
Mean	725,854	715,372	708,963	709,914	709,937	709,682
Standard deviation	31,094	30,269	2,211	465	1,379	1,010
Variation coefficient	0.043	0.042	0.003	0.001	0.002	0.001
Sum	22,501,483	22,176,529	22,007,336	21,977,845	21,298,120	21,290,466
Sum, % difference	1.4%		0.1%		<0.1%	

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January 24, 2025

Brent Brown
Jacobs Engineering
1610 N. 2nd Street
Suite 201
Milwaukee, WI 53212

RE: Summary comparison between City of Waukesha Clean Water Plant and USGS return flow Monitoring

Dear Brent,

I am pleased to provide a summary of the City of Waukesha's return flow monitoring at the facility located on W. Oakwood Rd in Franklin, WI for the period **October through December 2024.** The same as prior comparisons, daily volumes measured by the USGS were generally within 1% of those measured by the Clean Water Plant (CWP) maintained by the City of Waukesha. Differences greater than 1% were attributed to erroneous patterns in observed discharge, pump maintenance at the CWP, and gaps in data due to equipment malfunction. Additional detail is provided herein for your review. Please do not hesitate to contact me should you have any questions.

Sincerely,

William Selbig
Research Hydrologist
USGS – Upper Midwest Water Science Center

Waukesha Clean Water Plant Flow Monitoring: OCTOBER - DECEMBER 2024

USGS measured daily volumes were generally within 1% of those recorded by the CWP. There were two instances when percent differences between daily volumes exceeded 2% (table 1).

Table 1. Days in which percent differences between daily volume measured by the USGS and CWP exceeded 2 percent. [volumes are in cubic feet].

Date	USGS	CWP	Percent Difference
10-Oct	627,471	710,503	12
11-Oct	658,674	709,331	7

Closer inspection of the hydrograph for these dates showed an anomaly in discharge pattern between USGS and CWP on October 10. Figure 1 shows each hydrograph following a similar pattern of rise and fall up to approximately 10 AM. The USGS time series appears to be slightly behind the CWP. This is due to the travel time required between the pump and the USGS observation point. The pattern is disrupted between approximately 10AM and 10PM. It is difficult to understand why this occurs; however, multiple restarts of the return flow pumps due to maintenance on October 10, as reported by the CWP, may have contributed to these discrepancies. The percent difference on October 11 (table 1) was due to a gap in data as a result logger malfunction. This was corrected approximately 2 hours after the error was discovered.

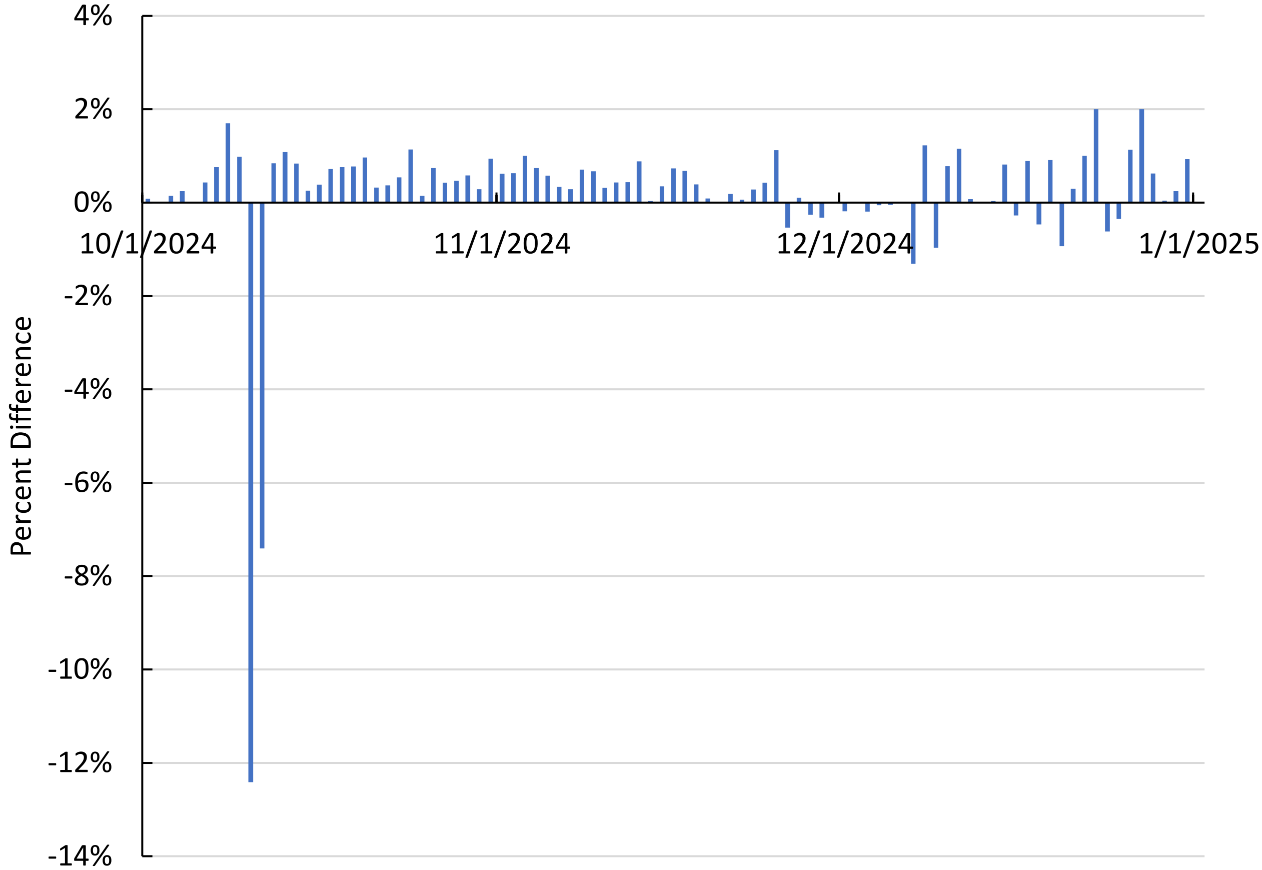


Figure 2. Percent difference between the USGS and CWP daily volume in October through December 2024. A positive value indicates USGS flow measurement is greater than the CWP's measurement.

There was little variation in daily volume among and between each month with median values ranging from approximately 709,688 to 713,330 cubic feet and coefficients of variation less than or equal to 0.12 (table 2). Monthly sums were similarly consistent with December having slightly more volume than October and November. November, having one less day than October or December, had the lowest monthly volume. Like daily volumes, differences between monthly sums were generally within 1 percent (table 2). The discrepancies in discharge observed on October 10-11 resulted in a 2% difference when summed over the month. The range of percent differences presented in figure 2 and table 2 is considered acceptable and within the accuracy of the meter used to measure discharge at +/- 2 percent. The findings during this quarterly reporting period are consistent with past analyses starting in October 2023.

Table 2. Summary statistics for daily return flow volumes measured by USGS and CWP, October – December 2024.

Statistic	OCTOBER		NOVEMBER		DECEMBER	
	USGS	CWP	USGS	CWP	USGS	CWP
Days	31	31	30	30	31	31
Minimum	627,471	240,716	704,984	682,048	692,495	706,951
Maximum	726,909	714,663	717,403	712,255	731,707	710,343
Median	713,330	709,688	712,624	709,881	710,093	709,875
Mean	709,383	694,663	712,228	708,677	711,233	709,623
Standard deviation	18,405	84,266	2,559	5,232	7,528	826
Variation coefficient	0.03	0.12	<0.01	0.01	0.01	<0.01
Sum	21,990,859	21,534,552	21,366,839	21,260,311	22,048,232	21,998,324
Sum, % difference	2%		<1%		<1%	

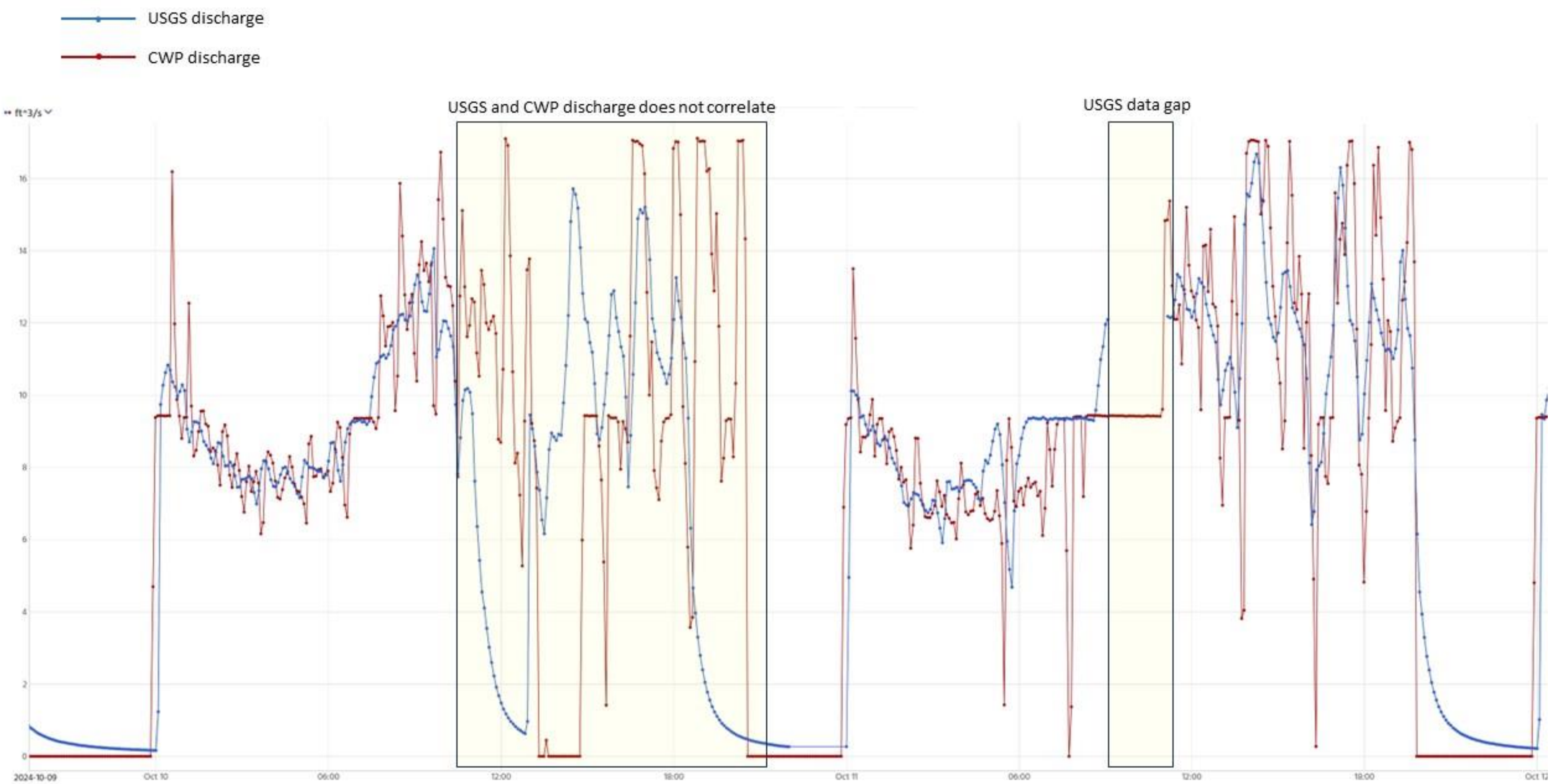
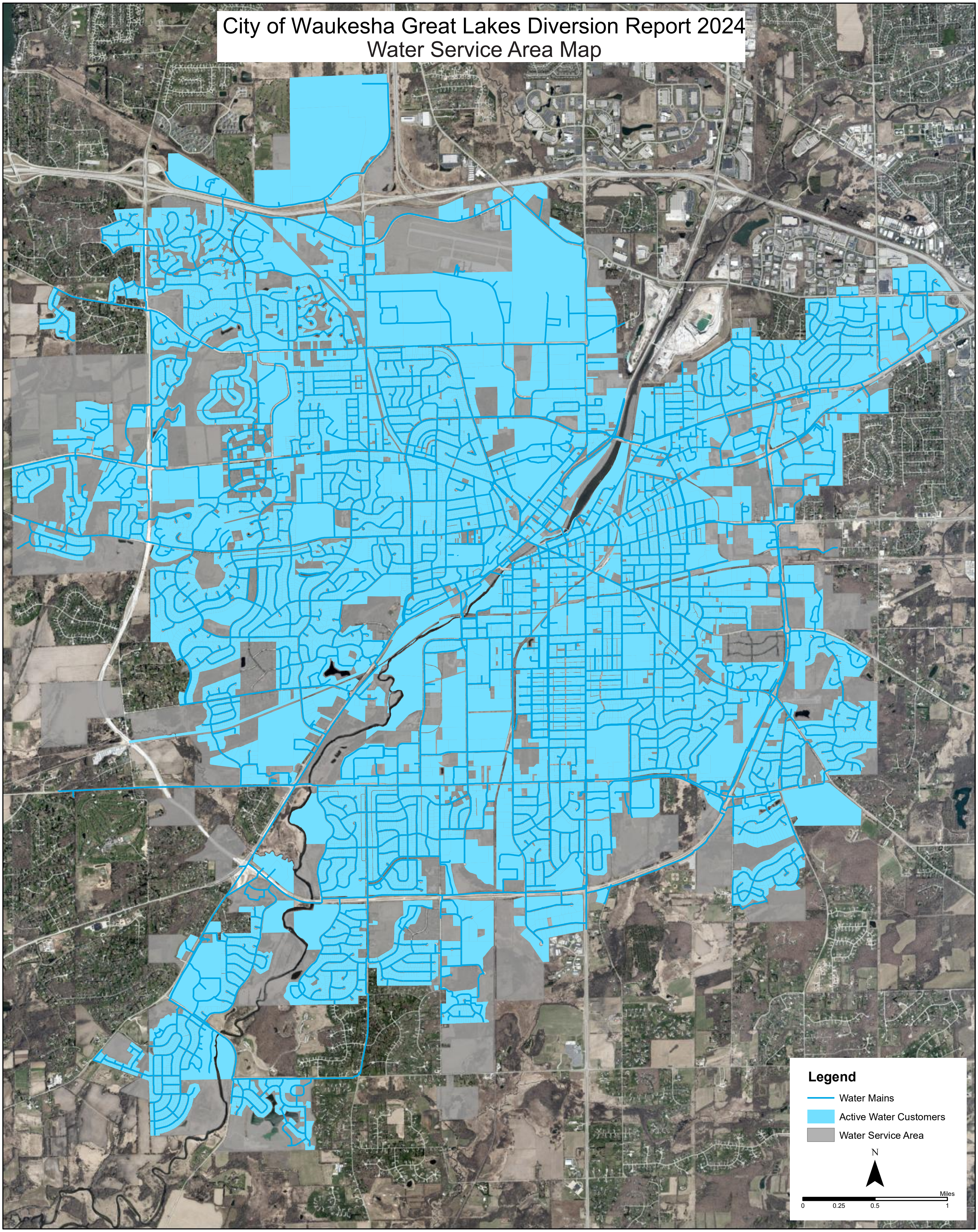


Figure 1. Comparison of USGS and CWP discharge time series for October 10-11, 2024. The shaded areas indicate periods when USGS and CWP observed discharge did not follow expected rise and fall patterns or a gap in data.

Appendix D. 2024 Service Area Map


City of Waukesha Great Lakes Diversion Report 2024
Water Service Area Map
Legend
Water Mains
Active Water Customers
Water Service Area
N
Miles
0
0.25
0.5
1

Appendix E. WDNR Approval of Extended Well Abandonment Agreement (November 2023)

State of Wisconsin
DEPARTMENT OF NATURAL RESOURCES
141 NW Barstow St., Room 180
Waukesha, WI 53188

Tony Evers, Governor
Adam N. Payne, Secretary
Telephone 608-266-2621
Toll Free 1-888-936-7463
TTY Access via relay - 711

November 24, 2023

Waukesha Water Utility
Daniel Duchniak – Water Utility General Manager
115 Delafield St.
Waukesha, WI 53188

PWSID#: 26802380
Region: Southeast Region
County: Waukesha
File Code: 3300

Subject: Approval of Extended Well Abandonment Agreement for Utility Wells

Dear Mr. Duchniak:

The Wisconsin Department of Natural Resources, Division of Water, Bureau of Drinking Water and Groundwater, is conditionally approving the request for the following in accordance with NR 810.22.

Water system name: Waukesha Water Utility (Utility)
Date received: 11/24/2023
Length of time extension: None
Utility Representative: Daniel Duchniak. PE
Regional DNR Contact: Thanintr Ratarasarn – SE Waukesha
Project description: Extended Well Operation Agreement for Utility wells

Per NR 810.22, an emergency well is a well that is not routinely used. The well owner may obtain a written Extended Well Abandonment Agreement with the Department to allow a normally unused or standby well to remain operational and to delay well abandonment for the following Utility wells.

Well # 3 (WUWN BH429)
Well # 5 (WUWN BH431)
Well # 6 (WUWN BH432)
Well # 7 (WUWN BH433)
Well # 8 (WUWN BH434)
Well # 9 (WUWN BH435)
Well # 10 (WUWN BH436)
Well # 11 (WUWN RL255)
Well # 12 (WUWN RL256)
Well # 13 (WUWN WK947)

Approval conditions related to Chapter NR 809, NR 810, and NR 811, Wis. Adm. Code:

1. All wells shall be placed into emergency status no later than **December 31. 2023.**
2. Per the Great Lakes Compact Council approval and the DNR diversion approval, the wells shall not be used as part of the Utility's regular water supply and only used for emergency purposes.
3. The water system will restrict the use of the well if the water quality exceeds the primary drinking water standards to emergency use of no more than 2 days per quarter. The Department may authorize an extended period of use for an individual event if contacted by the Utility.

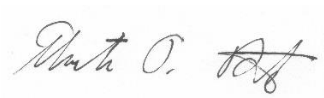
4. The water supplier shall notify all customers of the use of the well. A **Tier II** public notice, in accordance with **NR 809.52** shall be issued if this well is used.
5. The well water entering the distribution system may not exceed any bacteriological or nitrate drinking water standards.
6. The well water may not contain any volatile organic or synthetic organic contaminant levels exceeding the maximum contaminant level or MCL that could lead to further water quality degradation of the groundwater.
7. The well owner agrees to a 5 year cycle of reevaluation. Where the agreement is continued, it shall be renewed in writing every 5 years.
8. A 6-year cycle for water quality monitoring is established.
9. Bacteriological testing is conducted quarterly from the well.
10. Nitrate is monitored annually from the well.
11. The well meets current well construction and pump installation standards.
12. The well owner agrees to televise any well in excess of 70 years old at least once every 15 years.

Approval conditions related to other Department requirements: None

Approval constraints: This approval is based upon the representation that the information obtained by the department from the Waukesha Water Utility is complete and accurately represents the project being approved. Any approval of plans that do not fairly represent the project because they are incomplete, inaccurate, or of insufficient scope and detail is voidable at the option of the department.

If you have any questions, please do not hesitate to contact me by telephone at 262-765-0912, or by e-mail at Thanintr.Ratarasarn@Wisconsin.gov.

Sincerely,



Thanintr (Tony) Ratarasarn, MS, PE
Drinking Water Engineer

Cc: DG Files – Southeast Region
DG/5 - Madison

Attachments: Extended Well Abandonment Agreement Permit

EXTENDED WELL ABANDONMENT AGREEMENT BETWEEN THE WISCONSIN DEPARTMENT OF NATURAL RESOURCES (DEPARTMENT) AND THE CITY OF WAUKESHA WATER UTILITY

PURPOSE

Per NR 810.22, an emergency well is a well that is not routinely used. The well owner may obtain a written extended well abandonment agreement with the department to allow a normally unused or standby well to remain operational and to delay well abandonment. This Agreement between the Department and the City of Waukesha Water Utility (PWSID # 26802380) has been written to satisfy the requirements of NR 810.22, Wis. Adm. Code. The City of Waukesha Water Utility owns and operates a well that is no longer used and shall place the following well into emergency status:

- Well # 3 (WUWN BH429)
- Well # 5 (WUWN BH431)
- Well # 6 (WUWN BH432)
- Well # 7 (WUWN BH433)
- Well # 8 (WUWN BH434)
- Well # 9 (WUWN BH435)
- Well # 10 (WUWN BH436)
- Well # 11 (WUWN RL255)
- Well # 12 (WUWN RL256)
- Well # 13 (WUWN WK947)

This agreement allows the City of Waukesha Water Utility the use of the above well for emergency purposes where the loss of the primary water source would necessitate the use of this well to protect health and human safety.

REQUIREMENTS

The City of Waukesha Water Utility agrees to comply and shall continuously comply with the following requirements for the well for which this agreement applies:

1. Per the Great Lakes Compact Council approval and the DNR diversion approval, the wells shall not be used as part of the Utility's regular water supply and only used for emergency purposes.The water system will restrict the use of the well if the water quality exceeds the primary drinking water standards to emergency use of no more than 2 days per quarter. The department may authorize an extended period of use for an individual event if contacted by the Utility.
2. The water supplier shall notify all customers of the use of the well. A Tier II public notice, in accordance with NR 809.52 shall be issued if this well is used.
3. The well water entering the distribution system may not exceed any bacteriological or nitrate drinking water standards.
4. The well water may not contain any volatile organic or synthetic organic contaminant levels exceeding the maximum contaminant level or MCL that could lead to further water quality degradation of the groundwater.
5. The well owner agrees to a 5 year cycle of reevaluation. Where the agreement is continued, it shall be renewed in writing every 5 years.
6. A 6-year cycle for water quality monitoring is established.
7. Bacteriological testing is conducted quarterly from the well. Nitrate is monitored annually from the well.
8. The well meets current well construction and pump installation standards.
9. The well owner agrees to televise any well in excess of 70 years old at least once every 15 years.

SIGNATURES

This agreement shall expire five years the date the well is placed into emergency status. The evaluation may be completed by the Department prior to the five-year anniversary, if the Department determines it is necessary.

[signature]	11/28/2023	[signature]	11/28/2023
Thanintr Ratarasarn, PE Regional Water Supply Engineer WI Department of Natural Resources	Date	Daniel Duchniak, PE Water Utility General Manager City of Waukesha Water Utility	Date

Appendix F. Pharmaceutical and Personal Care Products Reduction Program – 2024 Annual Report

Memorandum

Subject	**City of Waukesha Pharmaceutical and Personal Care Products Reduction Program – 2024 Annual Report**
Project Name	City of Waukesha 2024 Diversion Reporting
From	Clean Water Plant: Plant Manager, Pretreatment Coordinator, Administrative Assistant Solid Waste: Solid Waste Coordinator Water Utility: Operations Manager
Date	January 13, 2025

The City of Waukesha, Wisconsin (City) received approval of its application for diverting Lake Michigan water with return flow on June 24, 2016 (Application Approval) and June 29, 2021 (Diversion Approval). As a condition of the approvals, the City is required to implement a Pharmaceutical and Personal Care Products (PPCP) Reduction Program. The purpose of this memorandum is to summarize the progress of the PPCP Reduction Program in 2024.

1. Background

The City operates the Clean Water Plant (CWP) to provide wastewater treatment to City residents and a small number of surrounding residential and commercial areas. There are various existing programs required as part of the CWP discharge permit that reduce the volume of wastewater and constituents in the wastewater conveyed to the CWP. One of these programs includes providing education about the importance of proper disposal of PPCPs, as well as promoting pharmaceutical collection boxes and collection events. The CWP also has partnered with the City's Recycling and Solid Waste Division, the City's Communications and Engagement Group, the City Police Department, and Waukesha County to coordinate efforts related to the PPCP Reduction Program. Examples of past PPCP reduction efforts by the City include the following:

- Promoting continuous pharmaceutical disposal collection boxes or kiosks at multiple locations within the City.
- Sponsoring National Prescription Drug Take-Back Day collection events twice per year – typically, one event in April and a second event in October.
- Providing public education through multiple platforms, including the City, Department of Public Works (DPW), and CWP websites; City weekly email news; DPW mailed newsletters; direct water and sewer bill inserts; and social media postings on Facebook, City televisions within City Hall, and on community message boards.

The PPCP Reduction Program has focused primarily on educating the public, promoting pharmaceutical take-back events, and directly supporting the proper disposal of residential prescription and over-the-counter medications. The following sections provide a summary of the program accomplishments.

2. Source Reduction Through Education

The following resources were reviewed for consideration in providing public education:

- Waukesha County Sheriff's Department – Prescription and Over-the-Counter Medicine Collection Program
- Wisconsin Department of Natural Resources (WDNR) – How to Safely Dispose of Household Pharmaceutical Waste
- WDNR – Pharmaceutical and Personal Care Products in the Environment
- WDNR – Wisconsin Household Pharmaceutical Waste Collection: Challenges and Opportunities (UW Extension, October 2012)
- Earth 911
- Product Stewardship Institute
- Wisconsin Department of Health Services – Dose of Reality Partner Materials
- Water Environment Federation – Household Waste Disposal Chart
- Wisconsin Department of Justice – Drug Take-Back Day Information
- Wisconsin Department of Justice – Permanent Drug Drop Box Locations
- U.S. Department of Justice – Year-Round Drop-Off Locations – Search Utility
- U.S. Drug Enforcement Administration (DEA) – Take-Back Day

The following educational materials and promotional materials were made available to residents in 2024:

- Attended Waukesha Night Out event on July 31, 2024, and set up a booth for PPCP education (Figure 2-1).
  - Created and distributed trifold flyer educating the public on proper personal care product disposal (Figure 2-2).
  - Created and displayed poster educating the public on proper PPCP disposal (Figure 2-1).

Figure 2-1. Waukesha Night Out Booth Setup for PPCP Education

Figure 2-2. Trifold Flyer Educating the Public on Proper Personal Care Product Disposal

- Educated the public attending CWP tours during Waukesha Unlocked Event on October 12 and 13, 2024.
  - Distributed trifold flyer to educate the public on personal care product disposal (Figure 2-2).
  - Verbally educated public on proper pharmaceutical disposal.
- Included information regarding PPCPs in two quarterly DPW newsletters, which are sent to approximately 21,000 households.
  - Spring – Promoted not flushing unused medication down the toilet or drain and where to properly dispose of unwanted medications.
  - Winter – Disposal Guide outlining how to properly dispose of pharmaceuticals.

Figure 2-3 includes an example of a PPCP article in the DPW newsletter promoting personal care product disposal best practices.

Figure 2-3. Example Personal Care Products Disposal Article in the Spring 2024 DPW Newsletter

Never Flush Drugs Down the Drain

Every day many people use prescription and over-the-counter drugs that contain unique compounds that could end up in our local waterways.

Due to the widespread use of these products and greater analytical sensitivity, very tiny amounts of these drugs can be detected in conventional treatment plant outflow. While there is no evidence these traces pose a risk to human health, scientists can sometimes find interference with aquatic organisms, and studies continue.

Meanwhile, it's important to control what we flush or put down the drain, and everyone's help is important.

You can help keep our water resources clean by simply **not flushing unused medication down the toilet or drain**. Take advantage of the City's secure drug disposal box at the Police Department at 1901 Delafield St. in the lobby. Not only will you be helping protect the environment, but you'll also help prevent the misuse or abuse of unwanted medications in our homes and community. Thank you for doing your part.

- The Waukesha Police Department provided an informational flyer created by the DEA for the October National Drug Take-Back Day. Flyers were available to post in stores, cafes, and restaurants and at the public library.
- Created and distributed trifold flyer at City Hall and the Waukesha Public Library (Figure 2-2) educating the public on proper personal care product disposal.
- Included a "Don't Flush That" article promoting proper disposal of PPCP in the City's February 2024 e-newsletter. The e-newsletter typically is sent to more than 7,000 email addresses.
- Included an article promoting the Police Department Drug Drop Box in the City's February 2024 e-newsletter. The e-newsletter typically is sent to more than 7,000 email addresses.
- Included articles promoting Drug Take-Back Day in the City's April and October 2024 e-newsletter. The e-newsletter typically is sent to more than 7,000 email addresses.
- The CWP website includes information about PPCPs as well as website links for:
  - Additional educational material on the WDNR's Pharmaceutical and Personal Care Products webpage
  - Resources regarding proper disposal of PPCPs and best practice recommendations
  - The City's drug disposal locations on the City's website under the Drug Disposal Program

  Figure 2-4 shows information regarding PPCPs on the CWP website.

Figure 2-4. Example PPCP Information on the CWP Website

Prescriptions & Personal Care Products

Doing some spring cleaning and clearing out your medicine cabinet? Stop before you flush old or unwanted prescription, over-the-counter medications, or other personal care products down the toilet or drain. Studies have shown that pharmaceuticals and personal care products are present in the environment. People in Wisconsin use and discard large quantities of over-the-counter medications, prescriptions and personal care products every year. Flushing these products down the drain may contaminate our lakes and rivers and affect fish and wildlife. There is growing evidence that these products may be affecting the environment in unintended ways, and unused medications in homes may be misused or abused.

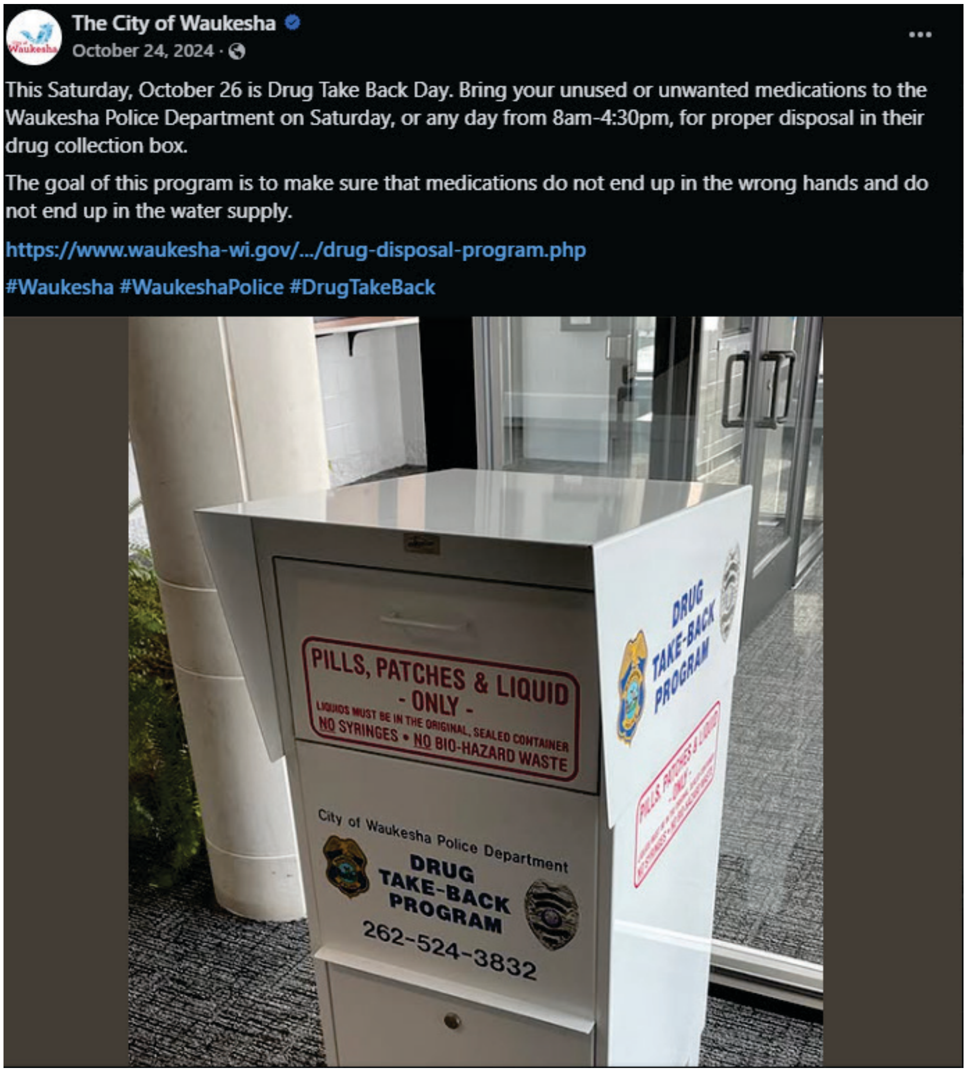
For more information:

- Pharmaceutical Waste and the Environment - Wisconsin Department of Natural Resources (DNR)
- Household Waste Disposal Chart - Water Environment Federation
- Drug Disposal Program - City of Waukesha Police Department

- Social media articles were posted to the City's Facebook, Instagram, and X (formerly Twitter) accounts. The social media posts included articles such as the following:
  - "Police Department Drop Box" – Information about the permanent pharmaceutical drop box at the City Police Department on 2/3/2024.
  - "Toilet is Not a Trash Can. Only Toilet Paper in the Toilet" – Information about proper pharmaceutical disposal on 2/26/2024.
  - "Drug Take-Back Day" – Promoting Drug Take-Back Day on April 27, 2024.
  - "National Drug Take-Back Day" – Promoting National Drug Take-Back Day on October 26, 2024.

  Figure 2-5 includes an example of a social media post promoting the October National Drug Take-Back Day.

Figure 2-5. Example Social Media Post Promoting the October National Drug Take-Back Day



- The City included a “Disposal Guide” on its waste collection website detailing disposal options for personal care products and pharmaceuticals.
- “Drug Disposal Program” and “Think Before You Flush” articles regarding best practices for PPCP disposal were posted to the City’s online “Residents Guide” and departmental websites for continuous availability to residents.

Figure 2-6 shows the continuous drop box information provided by the City in its online “Residents Guide.”

Figure 2-6. Example Information about the Police Department Pharmaceutical Continuous Drop Box Published in the City's "Residents Guide"

3. Source Reduction Through Collection and Reuse

Collection events and continuous collection locations are a central part of the PPCP program. The events, continuous drop box locations, and quantity of collected PPCP are summarized in Table 3-1.

Table 3-1. Quantity of PPCP Collected in 2024

Date	Event Name or Location	Quantity and Units
October 2023 to April 2024	City Police Continuous Drop Box	571.2 lbs
April 2024 to October 2024	City Police Continuous Drop Box	690.4 lbs
April 27, 2024	National Drug Take-Back Day Event	135.8 lbs
October 26, 2024	National Drug Take-Back Day Event	177.8 lbs
	Total	1,575.2 lbs

lbs = pounds

The PPCP reduction program coordinators have discussed expanding the number of events and continuous drop box locations, including completing the following activities:

- Confirmed new drop box locations available within the City in 2024.
- Verified existing locations and contact information for continuous drop boxes for City police, County sheriff, and local pharmacies (included in Table 3-2).

Table 3-2. Locations of Continuous Drop Boxes

Location Name	Address
Waukesha Police Department (in front lobby)	1901 Delafield Street, Waukesha
Waukesha County Sheriff's Department (in lobby)	515 W. Moreland Boulevard, Waukesha
Waukesha Memorial Hospital (in pharmacy)	725 American Avenue, Waukesha
Walgreens	221 E. Sunset Drive, Waukesha
Meijer (in pharmacy)	801 E. Sunset Drive, Waukesha

For significant sources of pharmaceuticals, the following activities were completed:

- Researched, discussed, and developed potential educational material geared toward entities that are potential significant sources of pharmaceuticals.
- Developed a list of potential significant sources of pharmaceuticals for future coordination regarding education materials and source reduction (Tables 3-3 and 3-5).
- Contacted all potential significant sources of pharmaceuticals to ascertain and document their pharmaceutical collection and disposal practices.

Table 3-3. List of Potential Significant Sources of Pharmaceuticals

Type	Source
Hospitals	Ascension Wisconsin Hospital – Waukesha Rehabilitation Hospital of Wisconsin Waukesha Memorial Hospital
Clinics	Affiliated Dermatologists Aurora Urgent Care Concentra Urgent Care Doenier Family Medicine Endodontic Associates Froedtert Westbrook Health Center GI Associates Iris Health Clinic Moreland Endoscopy Center Moreland ENT Moreland Ob-Gyn Associates Oral and Maxillofacial Surgery ProHealth Care – Moreland Surgery Center ProHealth Care Medical Associates ProHealth Medical Group ProHealth Urgent Care Retina & Vitreous Urology Associates Waukesha County Dept. of Health & Human Services Waukesha Eye and Vision Clinic Waukesha Family Medicine Residency Center

Type	Source
	Waukesha Family Practice Clinic Waukesha Pediatric Associates Waukesha Surgical Specialists WisHope
Pharmacies	CVS Pharmacy Genoa Healthcare Meijer Pharmacy Moreland Plaza Pharmacy ProHealth Pharmacy Waukesha/Waukesha Memorial Hospital Walgreens Walmart Pharmacy
Veterinary Clinics/Animal Shelters	Center for Animal Rehabilitation Cream City Kitty Clinic Harmony Pet Clinic Humane Animal Welfare Society VCA Associates in Pet Care Animal Hospital Waukesha Walk-in Vet Clinic Westown Veterinary Clinic Wisconsin Veterinary Referral Hospital
Assisted Living Facilities	Avalon Square Heritage Memory Care New Perspective Senior Living – Waukesha Oak Hill Terrace Senior Living
Nursing Homes/ Community-based Residential Facilities	Aria of Waukesha Christian Homes Kensington Care and Rehab Center Linden Grove Waukesha Mission Creek Senior Living Summit Woods

Pharmaceutical disposal practices among the potential significant pharmaceutical sources are presented in Table 3-4.

Table 3-4. Pharmaceutical Disposal Summary from Potential Significant Sources

Disposal Method	Percentage of Use
Vendor	60%
Drop box collection site or other pharmacy	14%
Destruction media or absorbent	14%
No pharmaceutical dispensing or disposal	12%

Contacts with potential personal care product (PCP) sources in 2024 (Table 3-5) revealed that hospitals are similar to hotels in that PCPs that are not completely used are placed in the trash as the best disposal method. Retail establishments, including pharmacies and department stores, universally use contracted vendors such as return centers/reverse distributors and environmental management services to dispose of expired or unsold PCP inventory. Table 3-5 presents a list of potential significant sources of PCPs.

Table 3-5. List of Potential Significant Sources of PCPs

Type	Source
Hospitals	Ascension Wisconsin Hospital – Waukesha Rehabilitation Hospital of Wisconsin Waukesha Memorial Hospital
Pharmacies	CVS Pharmacy Moreland Plaza Pharmacy Walgreens
Department Stores	Meijer Target Walmart Supercenter

Non-prescription PCPs such as hair care, lotions, and ointments are not accepted at collection events or continuous drop box locations. This is in part because they are not controlled substances. They may be part of residents' normal daily hygiene, and consequently disposal options simply include placing PCPs in garbage or solid waste receptacles. Reducing waste from disposing of unused PCPs through reuse opportunities has been considered, however, entities that may benefit from PCP reuse (for example, shelters) can receive more donated products than needed and there is concern that opened PCPs could be tampered with and present a safety hazard. These two issues severely limit reuse opportunities. Consequently, future PCP opportunities will likely focus on proper disposal if materials are discarded before the end of their useful life.

Additional PCP activities included:

- Reviewed general PCP educational information for use in updating Frequently Asked Questions, social media posts, and on associated City websites.
- Reviewed local ordinances and state laws related to PCP disposal best practices.
- Reviewed general PCP disposal and reuse best practices for consideration in future implementation.
- Reviewed additional opportunities for PCP reduction and reuse through the WDNR and U.S. Environmental Protection Agency (EPA).

4. Future Opportunities

The City has expanded its PPCP Reduction Program from efforts conducted prior to the diversion. However, additional activities that will be considered in 2025 and beyond could include the following:

- General PPCP and PCP Information
  - Monitor best practices regarding pharmaceuticals and personal care products provided by the EPA and WDNR.
  - Update list of acceptable PPCPs and PCPs for collection and disposal on City, CWP, Police, and Sheriff websites to be consistent and provide as much specificity as possible.

- Source Reduction through Education
  - Connect with local schools for publishing educational material in their district newsletters and other communication outlets or to provide educational materials as part of Earth Day instructional events.
  - Improve and expand the educational and awareness materials for significant PPCP sources.
  - Continue to develop and publish PPCP and PCP events and educational material on City Facebook, X, and Instagram accounts.
  - Continue to develop and publish content about PPCP and PCP by electronic methods such as the City's website and e-newsletters.
  - Continue to develop and publish content about PPCP and PCP in DPW newsletters.
  - Develop and publish content about PPCP and PCP in water/sewer bill inserts.
- Source Reduction through Collection and Reuse
  - Further inventory potentially significant PCP sources in the City besides hospitals, pharmacies, and department stores to provide educational materials on proper disposal options.
  - Despite initial limitations, continue exploring opportunities to connect PCP sources with users to provide PCP reuse opportunities (for example, connecting hotels with shelters for reuse of unopened PCP).
  - Continue discussions with pharmacies and veterinary clinics to expand continuous collection (drop box) locations.
  - Continue discussions with the Waukesha Police Department to expand collection opportunities at household hazardous waste events at the County's contracted collection site.
  - Further inventory potentially significant PPCP sources in the City besides hospitals, pharmacies, nursing homes, and veterinary clinics.
  - Further provide PPCP and PCP collection opportunities and information to educate the public by staffing events/booths to specifically promote the PPCP program.

Appendix G. Root River Data Collection Summary (Post Diversion: October 2023 through September 2024)

Root River Data Collection Summary
2024 Annual Reporting

Prepared For:

City of Waukesha

Prepared By:

Jacobs

February 2025

Contents

Tables

Figures

Attachment

Acronyms and Abbreviations

°C	degree(s) Celsius
°F	degree(s) Fahrenheit
µg/L	microgram(s) per liter
cfs	cubic foot/feet per second
CH2M	CH2M HILL, Inc.
City	City of Waukesha
CPUE	catch per unit effort
E. coli	*Escherichia coli*
fps	foot (feet) per second
F-IBI	fish index of biological integrity
HBI	Hilsenhoff Biotic Index
IBI	Index of Biotic Integrity for Fish Communities
Jacobs	Jacobs Engineering Group Inc.
M-IBI	macroinvertebrate index of biological integrity
mg/L	milligram(s) per liter
mgd	million gallons per day
MPTV	mean pollution tolerance value
mS/cm	milliSiemens per centimeter
NTU	nephelometric turbidity unit(s)
QAPP	Post-Return Flow Root River Monitoring and Quality Assurance Project Plan
S.U.	standard unit(s)
TSS	total suspended solids
USGS	U.S. Geological Survey
WDNR	Wisconsin Department of Natural Resources

1 Background

The City of Waukesha, Wisconsin (City) transitioned to a Lake Michigan water supply beginning in October 2023 consistent with the 2021 Diversion Approval granted by the Wisconsin Department of Natural Resources (WDNR). The final transition was complete in November 2023. The Diversion Approval requires the City to monitor the Root River to assess the impact of the return flow discharge and to report the assessment annually.

In preparation for the diversion, the City implemented a voluntary pre-diversion data collection program. The data collection began in 2017 to provide pre-diversion baseline water quality, flow, habitat, macroinvertebrate, and fish data (CH2M 2017). A summary of the pre-diversion data was included in Appendix G of the City's 2023 annual diversion report (Waukesha 2024). This report summarizes Root River monitoring and assessment of impact from the return flow following the first post-diversion reporting year October 2023 through September 2024 (the reporting period).

2 Return Flow Volume

2.1 Root River Flow

During the reporting period (first year of the post-diversion period), flow monitoring was completed at the City's Clean Water Plant (CWP). Table 2-1 summarizes monthly average return flow volumes to the Root River over this period. Return flow volumes were very consistent throughout the year, with an average daily flow of 5.22 million gallons and a standard deviation of ±0.77 million gallons. Contributing to the minor deviation was the target daily return flow, which changed from 5.15 million gallons per day (mgd) in 2023 to 5.26 mgd in 2024. The consistency of daily return flow results in no significant change to the periodicity of return flow.

The peak return flow was recorded at 6.63 million gallons on July 30, 2024, after the pump controls were inadvertently changed for that single day. Through a cooperative partnership with the City, the U.S. Geological Survey (USGS) maintains a flow gauge along the Root River approximately 760 feet upstream from the return flow outfall (USGS site 04087234). During the reporting period, the average daily return flow ranged from 0[1] to 66% of the combined river and return total flow.

Table 2-1. Reporting Period Root River and Return Flows

Month	Average Monthly Flow (mgd)			
	Root River	Return	Total Flow (Root + Return)	Return % of Total Flow
October 2023	44.30	4.51[a]	48.81	9.2%
November 2023	33.77	5.21[a]	38.99	13.4%
December 2023	65.68	5.08[b]	70.76	7.2%
January 2024	152.77	5.26	158.04	3.3%
February 2024	118.10	5.31	123.41	4.3%

[1] Occurred prior to the final transition to Lake Michigan water. Refer to the Diversion Approval Report for 2023 (Waukesha 2024).

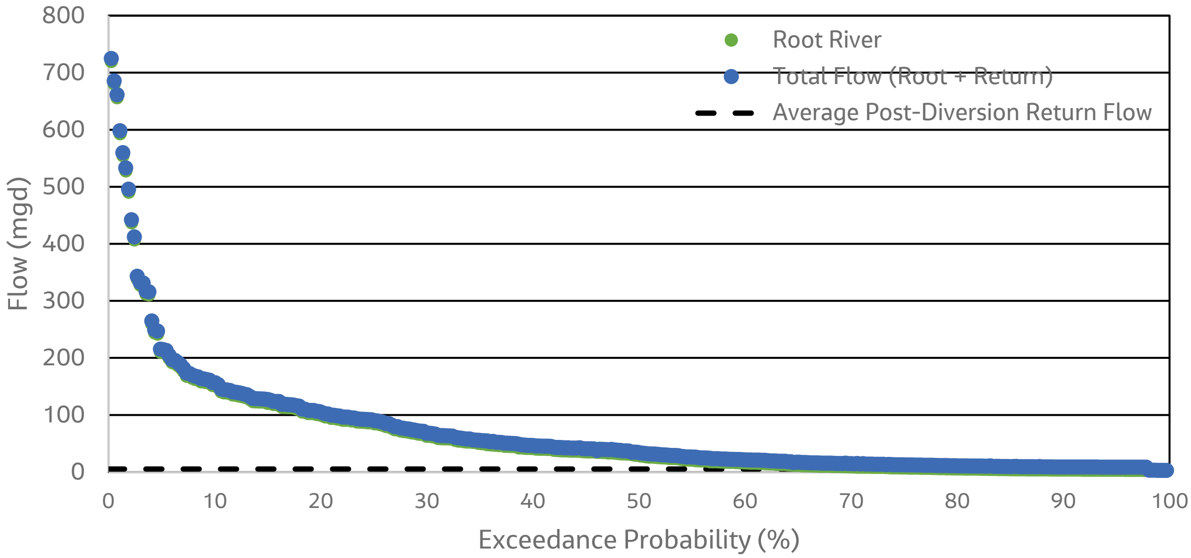
Month	Average Monthly Flow (mgd)			
	Root River	Return	Total Flow (Root + Return)	Return % of Total Flow
March 2024	93.53	5.31	98.84	5.4%
April 2024	105.11	5.31	110.42	4.8%
May 2024	73.27	5.31	78.58	6.8%
June 2024	25.32	5.31	30.63	17.3%
July 2024	24.78	5.35	30.13	17.8%
August 2024	19.13	5.31	24.44	21.7%
September 2024	4.45	5.31	9.76	54.4%

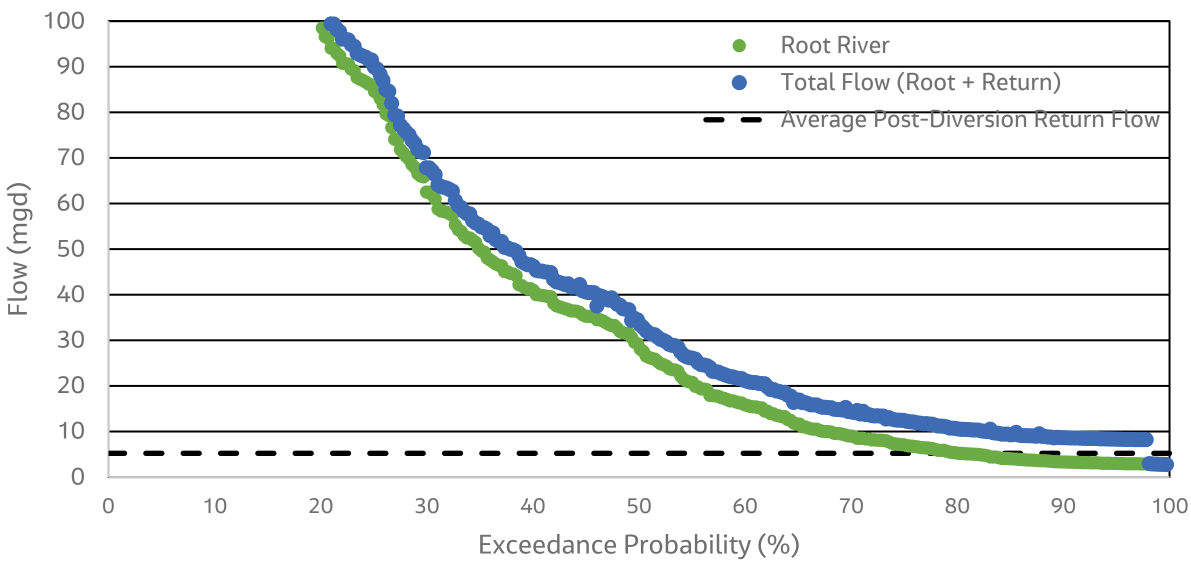
Notes:
[a] A transition month, thus not a full month of return flow
[b] The return flow gate malfunction resulted in pumps shutting down after 0.06 mgd was returned. The alarm did not alert CWP. This single day dropped the monthly average return flow slightly below the target.
All data noted by USGS to be provisional.

During the reporting period, USGS determined that return flow caused backwater extending from the return flow discharge to the 60th Street Root River flow gauge. This backwater was more noticeable during low-flow conditions following the removal of a beaver dam in December 2023. The backwater influenced Root River stage measurements, and therefore also flow measurements, throughout the reporting period. The USGS manually corrected all stream stage and flow data. To eliminate the return flow backwater from impacting Root River flow measurement, in coordination with the USGS and WDNR, the flow gauge was moved downstream for future post-diversion reporting years.

A flow duration curve of daily flows was developed for the Root River and the total flow (Root + return) to demonstrate the variability of the flow rate over time and the impact of the return flow on the river's hydrology (Figure 2-1).

Figure 2-1. Flow Duration Curve of Daily Root River Flow and Total Flow (Root + Return)





The daily return flow rates are well within the return flow rates projected in the Diversion Approval. The Root River flow exceeded the average daily return flow rate (5.22 mgd) 80% of the time. In other words, over the 366 days of the reporting period, the daily return flow exceeded Root River flow 73 days. With the consistent daily return flow, the flow duration curve with return flow also shifts upwards uniformly and the average daily return flow impacts the Root River hydrology uniformly.

These findings demonstrate that the return flow had minimal impact on the overall flow dynamics of the river, where the natural variability of the river's flow dominates river's hydrological regime.

2.2 Root River Water Level and Velocity

Using a hydraulic model was initially anticipated to evaluate changes in Root River water levels and velocity during the reporting period, assessing changes from the observed range of return flow and river flow over the year. The Southeastern Wisconsin Regional Planning Commission (SEWRPC) is developing a hydraulic model of the Root River for floodplain mapping that would replace the outdated HEC-2 model that currently exists at the return flow location. SEWRPC will share the model once complete, but the mainstem hydraulic model is still in draft form. Consequently, a hydraulic model is not available at this time, however the City will continue to coordinate with SEWRPC about potential use for this assessment as their model is developed.

As an alternative to the hydraulic model, USGS was consulted to estimate water levels from stage-discharge data collected as part of the river flow gaging. USGS did not recommend this approach because fallen trees, beaver activity, rain events, ice-out events, and the channel cross section morphology that currently affect the Root River channel would affect the stage-discharge data, and while the USGS has methodologies to correct flow estimates from these factors, correcting stage estimates was not recommended [2].

Velocity changes was estimated from the hydraulic model included in the Diversion Approval documents and summarized in the 2023 Pre-Diversion Root River Data Collection Summary Report (Jacobs 2024; Appendix G within Waukesha 2024). That hydraulic model calculated that a 12 mgd return flow rate results in an estimated 0.3 foot per second (fps) increase in water velocity during 2 mgd low-flow Root River conditions[3]. On the day with the highest percentage of return flow in the reporting period (September 15, 2024), the Root River had a very low flow of 2.73 mgd, with a return flow of 5.31 mgd. Under these conditions, the increase in water velocity with return flow is anticipated to be less than 0.3 fps.

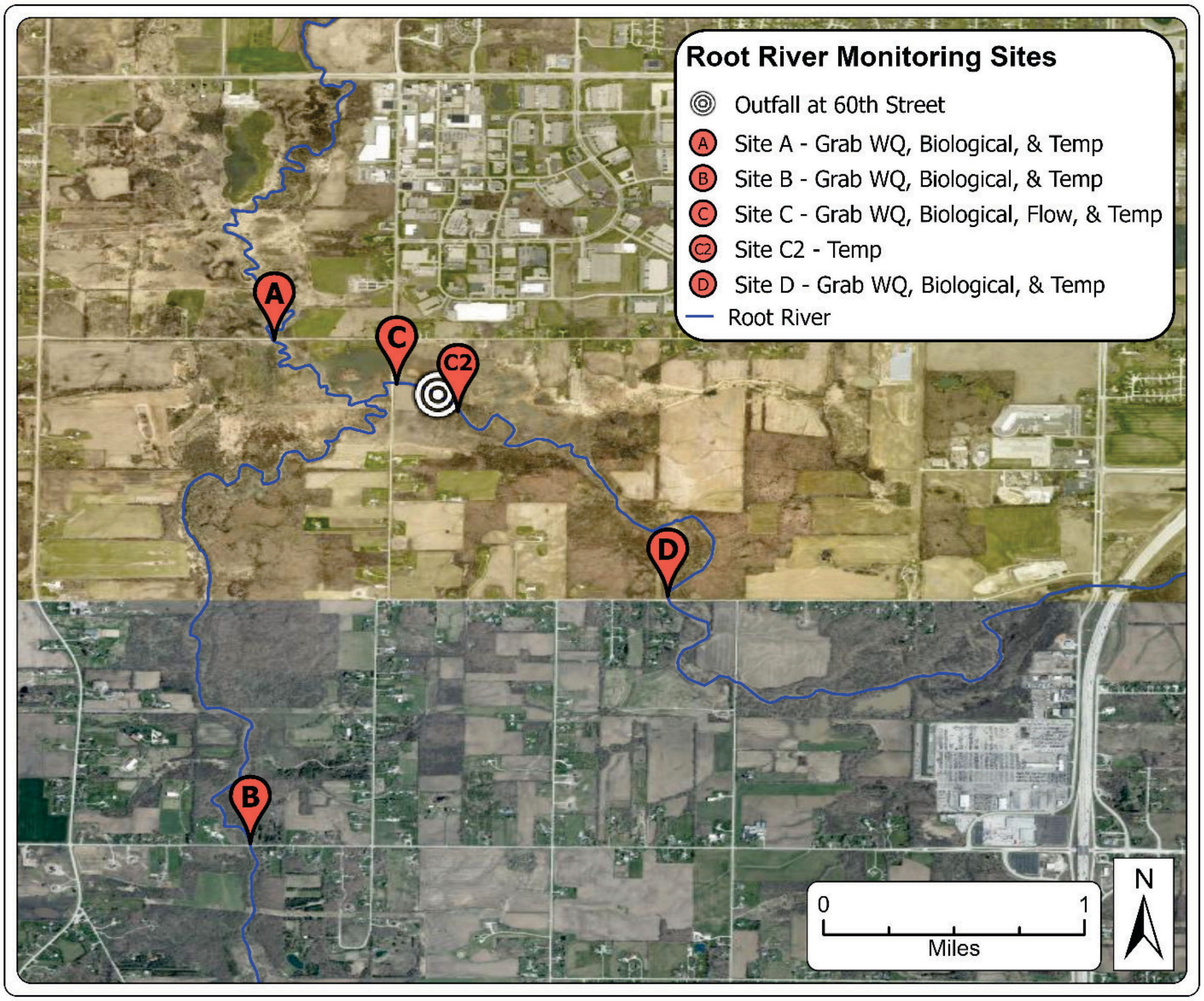
3 Monitoring Locations

Monitoring locations were upstream and downstream of the return flow outfall location (Figure 3-1) consistent with the Post-Return Flow Root River Monitoring and Quality Assurance Project Plan (Jacobs 2023; QAPP). Monitoring during the reporting period also included chlorides and *Escherichia coli* (*E. coli)* at Sites C and D.

[2] Email Communication between Anthony Debonis, Kassidy O'Malley, Brent Brown, and Rob Waschbusch. Root River data. August 2 to August 5, 2024.

[3] Refer to Appendix K, Table 3, in Volume 4, City of Waukesha Return Flow Plan, of the City of Waukesha Application for Lake Michigan Diversion with Return Flow.

Figure 3-1. Monitoring Locations



Note: Monitoring during the reporting period also included chlorides and *E. coli* at Sites C and D.

4 Data Analysis

Statistical analysis was completed to evaluate the differences between the pre-diversion period and the reporting period, sampling site locations, and seasons. The Mann-Whitney U Test was selected because it is a non-parametric statistical test used to compare differences between two independent groups. This test is particularly useful when the data do not follow a normal distribution or when sample sizes are small, which were conditions met by the reporting period dataset for some parameters (Jamil 2024).

The use of this test allowed detection of differences in the distributions of two datasets with reliability and validity, including in the presence of outliers or non-normal data distributions. Statistical analyses were conducted for evaluating whether changes in temperature and water quality were statistically significant. Statistical significance was evaluated at a p-value of 0.05, where a p-value less than 0.05 indicates that the observed differences are statistically significant, while a p-value greater than 0.05 indicates that the differences are not statistically significant.

It is important to note that the pre-diversion dataset is more than six times larger than the single year of data included in this reporting period. The insight and reliability of the statistical analyses will increase as subsequent years of post-diversion data are collected and the size of the datasets balance. Consequently, definitive conclusions are not presented at this time when comparing pre-diversion period and current reporting period statistics.

5 Water Temperature

Continuous water temperature monitoring at Sites A, B, C, and D has been conducted by USGS since September 2016, and monitoring at Site C2 was initiated in October 2023 as part of the Post-Return Flow Root River Monitoring Plan. Two HOBOTemp temperature data sondes are used at Sites A, B, C2, and D. Temperature at Site C is captured by an automated USGS gauge and one temperature data sonde located near the right bank of the river.

Data from sondes are regularly offloaded and the sondes are maintained and redeployed according to USGS continuous monitoring protocols. Temperature data are collected at hourly intervals at Sites A, B, C2, and D, and at 15-minute intervals at Site C.

Ambient river water temperatures are seasonal at all sites, where water temperature is coldest in December and January, and warmest in July and August. During the cold winter months, data loss may occur because of river freezing as well as the removal of the automated USGS temperature gauge at Site C to prevent damage. While the temperature *gauge* is offline, the temperature *data sonde* continues to collect data. Therefore, at Site C, temperature data are a combination of measurements from the automated gauge and the data sonde.

5.1 Reporting Period Water Temperature

A summary of daily average water temperature statistics for the pre-diversion period and the reporting period is shown in Table 5-1. A daily average temperature was calculated by averaging the hourly or 15-minute data by calendar day.

Table 5-1. Temperature Statistics by Site Using Daily Average Temperature

Site	Average	Minimum	Maximum	5th Percentile	50th Percentile (Median)	95th Percentile	Data Count (n)[a]
Pre-Diversion (January 2016 through September 2023)							
A	52	32	82	32	51	76	2,548
B	53	32	84	32	51	77	2,550
C	54	32	83	32	53	77	2,313
D	54	31	83	32	53	77	2,296
Reporting Period (October 2023 through September 2024)							
A	55	32	81	33	55	74	344
B	54	32	82	33	53	74	366
C	54	32	82	33	53	74	366

Site	Average	Minimum	Maximum	5th Percentile	50th Percentile (Median)	95th Percentile	Data Count (n)[a]
C2	54	33	77	34	54	73	366
D	54	32	78	34	54	74	366

Note:
[a] Variation in daily average temperature data counts for each site in the pre-diversion period and the reporting period were observed because of impacts to data collection equipment at each site. Temperature data collection was impacted by sensor malfunctions, sensors freezing in the winter months, sensors being at or above water level during low flow conditions in the summer months, or sensors being damaged by debris and/or animals.

Average and median water temperatures in the reporting period were consistent with or slightly higher than the pre-diversion period for all sites. This suggests that the reporting period of October 2023 through September 2024 was warmer compared to an average or median year observed during the pre-diversion period.

This finding is consistent with additional reporting from the National Weather Service that the winter of 2023 and the entirety of 2024 were some of the warmest periods on record in Milwaukee since data reporting began in the 1800s[4]. These warming trends were observed regionally and nationally and were attributed to the combined impacts of climate change and El Niño in 2023[5].

For the reporting period, 5th percentile water temperature values were higher and 95th percentile water temperature values were lower for all sites compared to the pre-diversion period. This is expected because the pre-diversion period captured nearly 8 years of temperature data, including more extreme warm and cold temperatures, whereas the reporting period currently captures only 1 year of temperature data. On average, there are 6.7 times more water temperature data for the pre-diversion period compared to the reporting period for each site.

The maximum water temperature at Site D is noticeably cooler in the reporting period compared to pre-diversion conditions. This finding may suggest that the introduction of return flow has a cooling effect on river water temperature during the warmer months.

Mann-Whitney U Test analyses comparing pre-diversion water temperature to reporting period water temperature at each site are shown in Table 5-2. The results indicate that differences in temperature between the two data collection periods were statistically significant ($p<0.05$) only at Site A. For Sites B, C, and D, differences in water temperature between the pre-diversion period and the reporting period were not statistically significant. This suggests that, for most sites, temperatures observed during the reporting period thus far are within baseline conditions observed during the pre-diversion period. The results also suggest that, at Site A, there were additional influences causing an increase in average and median temperatures during the reporting period. However, this increase did not result in a substantial increase in temperatures at downstream sites.

[4] https://www.weather.gov/mkx/weatherstory

[5] https://www.noaa.gov/news/fall-2024-was-nations-warmest-on-record#:~:text=Year%20to%20date%20(YTD%2C%20January,warmest%20January%E2%80%93November%20on%20record

Table 5-2. Mann-Whitney U Test, Water Temperature between Pre-Diversion and Reporting Period

Site	Comparison	p-value	Median Values	
			Pre-Diversion	Reporting Period[a]
A	Pre-Diversion vs. Reporting Period	0.003	51	55
B	Pre-Diversion vs. Reporting Period	0.054	51	53
C	Pre-Diversion vs. Reporting Period	0.458	53	53
D	Pre-Diversion vs. Reporting Period	0.296	53	54

Note:
[a] Reporting Period is Post Diversion Year 1 between October 1, 2023, and September 30, 2024.

Water temperatures observed at all sites may be the result of multiple factors, including natural and seasonal variation, regional and global impacts from weather trends and impacts to water temperature upstream of Site A and Site B. Water temperature analyses in future years with a larger dataset will support an assessment into which of these factors, or other factors, have substantial influence on Root River water temperatures.

5.1.1 Temperature Differences Across Seasons

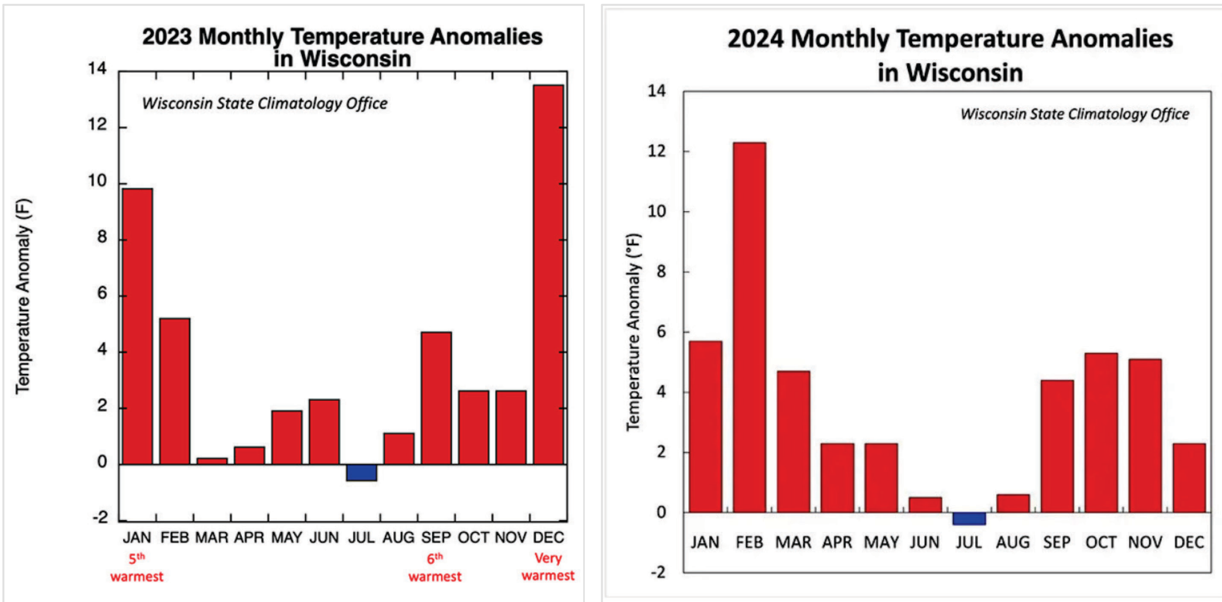
Ambient river water temperatures are seasonal at all sites, where water temperature is coldest in the winter months, and warmest in the summer months. The growing season, as defined in this monitoring program and including May through October, aligns with the spring and summer months. The non-growing season, as defined in this monitoring program and including November through April, aligns with the fall and winter months.

Mann-Whitney U Test analyses of daily average water temperature values during the growing season and non-growing season are shown in Table 5-3 for the pre-diversion period and reporting period. The differences in temperatures during the non-growing season are statistically significant ($p<0.05$). Therefore, from November through April, water temperatures were substantially warmer compared to pre-diversion conditions. This aligns with statewide temperature anomaly data for 2023 and 2024, shown on Figure 5-1, comparing monthly temperatures to the 1991 through 2020 average. December 2023 and February 2024 were the warmest December and February on record, respectively, and likely impacted the non-growing season median water temperature. In comparison, monthly temperature anomalies for May through September 2024 occurred at a smaller scale, thereby having a lesser impact on growing season water temperatures. For the growing season, the differences in temperatures during the pre-diversion period and reporting period are not statistically significant ($p>0.05$).

Table 5-3. Mann-Whitney U Test, Water Temperature Seasonality during the Pre-Diversion vs Reporting Periods

Season	Comparison	p-value	Median Values	
			Pre-Diversion	Reporting Period
Growing	Pre-Diversion vs. Reporting Period	0.066	68	68
Non-growing	Pre-Diversion vs. Reporting Period	4.81 e-41	37	40

Figure 5-1. 2023 and 2024 Monthly Temperature Anomalies in Wisconsin



Source: Wisconsin State Climatology Office[6,7]

5.1.2 Temperature Differences Across Sampling Sites

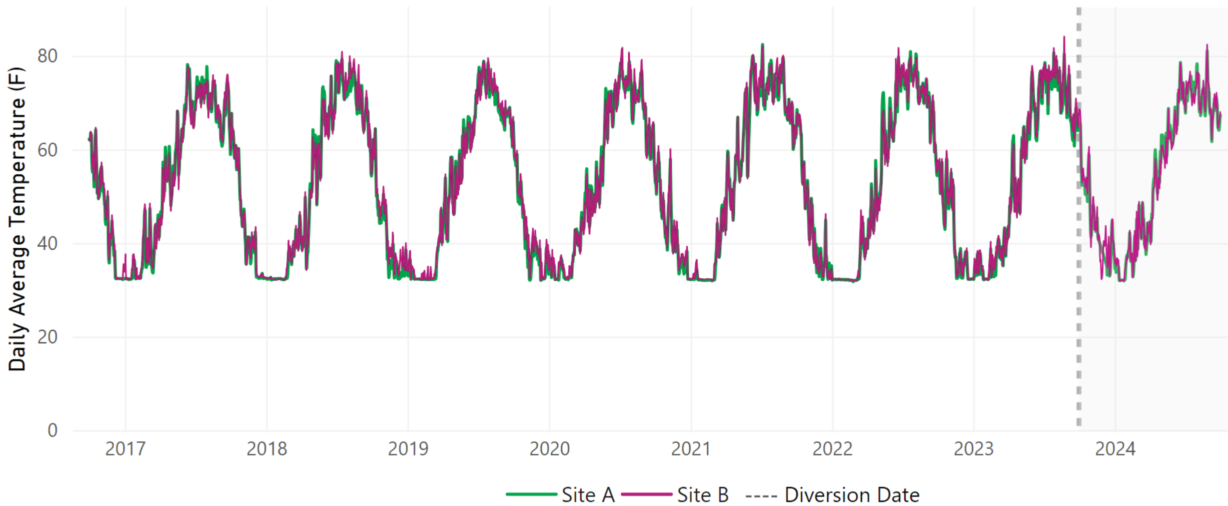
In addition to broad water temperature statistics, daily average water temperatures and differences in water temperatures across sites were assessed. Daily average temperatures in the pre-diversion and reporting period at Sites A, B, C, C2, and D are shown on Figures 5-2 and 5-3. Differences in daily average water temperature across all sites during the reporting period typically varied by less than 3 degrees Fahrenheit (°F).

5.1.2.1 Site A and Site B

Sites A and B were plotted together to compare water temperature variations from the canal (Site B) and the mainstem (Site A). Both Sites A and B are upstream of the return flow location. Figure 5-2 presents these comparison results.

[6] https://climatology.nelson.wisc.edu/wisconsin-year-end-climate-synopsis-for-2023/
[7] https://climatology.nelson.wisc.edu/wisconsin-annual-2024-climate-summary/

Figure 5-2. Daily Average Water Temperature at Sites A and B



Daily average water temperatures at Site A and Site B differed by 0 to 2°F, on average, and followed similar trends observed during the pre-diversion period. Generally, Site B appears to be warmer during the late summer through winter months (August through February), while Site A appears to be warmer during the early spring and summer months (April through July).

Mann-Whitney U Test analyses of daily average water temperature values at Site A and Site B are shown in Table 5-4. The results demonstrate that differences in temperatures at Site A and Site B during the pre-diversion period and report period were not statistically significant ($p>0.05$). This suggests that baseline conditions along the Root River Canal and mainstem resulted in similar water temperatures at Site A and Site B before and after the start of return flow.

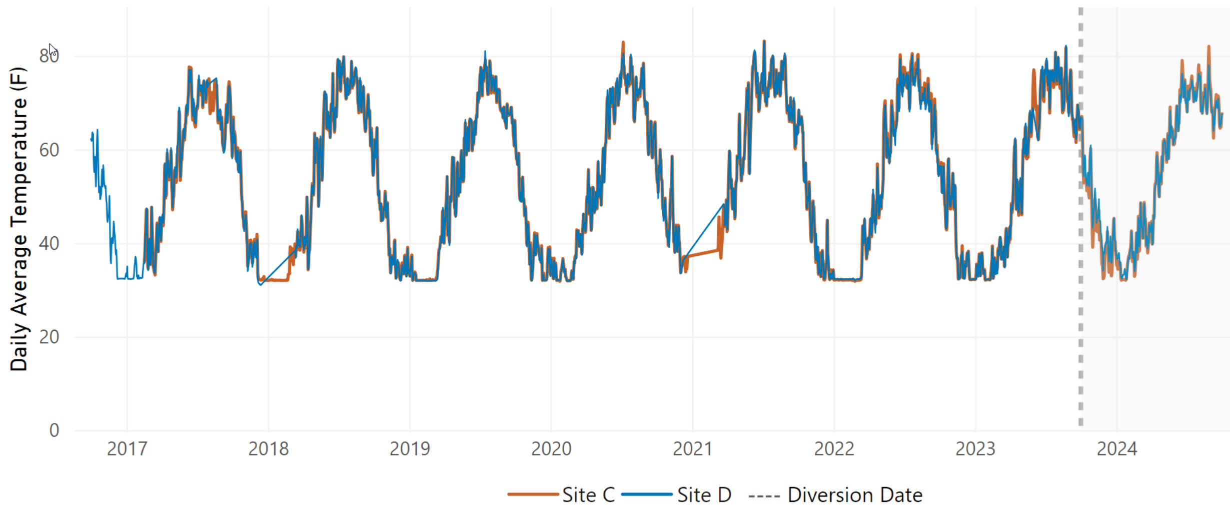
Table 5-4. Mann-Whitney U Test, Water Temperature at Site A and Site B

Program Phase	Comparison	p-value	Median Values	
			Site A	Site B
Pre-Diversion	Site A vs. Site B	0.165	55	53
Reporting Period	Site A vs. Site B	0.560	51	51

5.1.2.2 Site C, Site C2, and Site D

Sites C, C2, and D were compared to assess conditions of locations upstream (Site C), near downstream (Site C2), and farther downstream (Site D) of the return flow discharge location. Figure 5-3 presents these comparison results between Sites C and D.

Figure 5-3. Daily Average Water Temperature at Sites C and D



Notes:

Water temperature data at Site C were unavailable in the winter of 2018 because of a stream freezing event (3 days of data missing). Temperature data at Site C were unavailable in the winter of 2021 because of monitoring equipment removal to prevent freezing (76 days of data missing).

Water temperature data at Site D were unavailable in the winter of 2018 and the winter of 2021 because the temperature data sonde was impacted by ice events and/or animal interference (83 days and 103 days of data missing, respectively).

Daily average water temperatures at Site C and Site D differed by 0 to 3°F, on average. Temperature trends in the reporting period differed somewhat compared to the pre-diversion period. For most pre-diversion years, water temperatures at Site C were slightly warmer than at Site D in the fall to winter months (October through December), while Site D water temperatures were slightly warmer than at Site C in the early spring to summer months (April through August). However, 2022 was notably different than other pre-diversion years where water temperatures at Site C were warmer on average compared to Site D during the summer months (May through September). There are no known causes for this.

During the reporting period, water temperatures at Site D were warmer in the winter and cooler in the summer compared to Site C. In particular, daily average water temperatures at Site D were 0 to 3°F warmer than Site C during October, November, and December, whereas in pre-diversion years, Site C was warmer by 0 to 1°F during the same months. From June through September, Site D daily average water temperatures were 0 to 1°F cooler than Site C, similar to results observed in 2022.

These results suggest that temperatures observed during the reporting period at Site C and Site D may be similar to the natural variation as observed in the summer of 2022 and also may be influenced by other factors, such as return flow and regional weather trends.

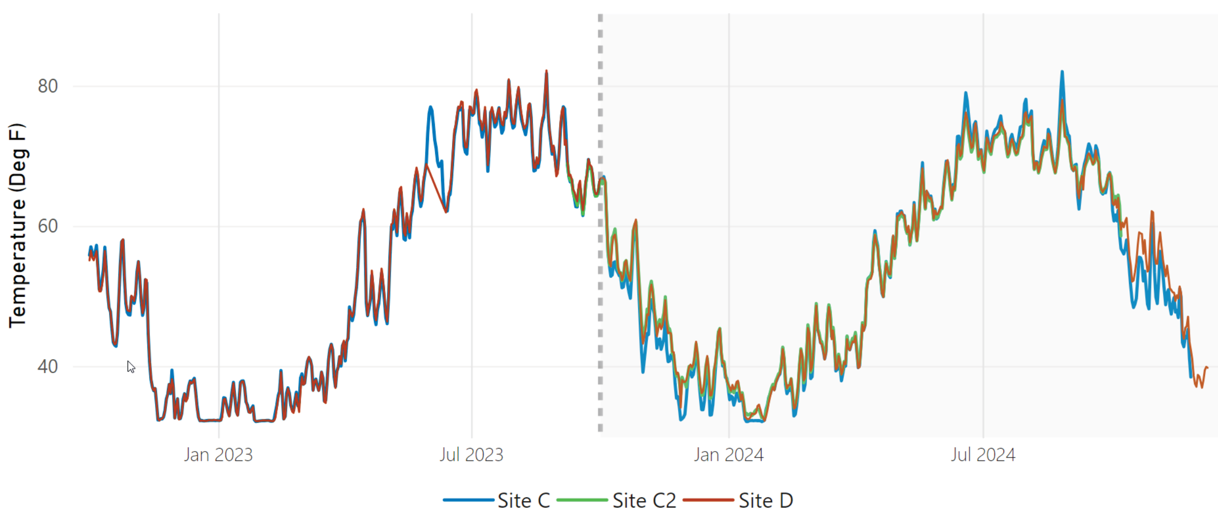
Mann-Whitney U Test analyses of daily average water temperature values at Site C and Site D are shown in Table 5-5. The results demonstrate that differences in temperatures during the pre-diversion and reporting period were not statistically significant ($p>0.05$). This suggests that for baseline conditions prior to the start of return flow, Site C and Site D demonstrated similar temperature because of natural, environmental, and other factors.

Table 5-5. Mann-Whitney U Test, Water Temperature at Site C and Site D

Program Phase	Comparison	p-value	Median Values	
			Site C	Site D
Pre-Diversion	Site C vs. Site D	0.687	53	54
Reporting Period	Site C vs. Site D	0.698	53	53

Figure 5-4 presents the results of a comparison of daily average water temperature monitoring at Sites C, C2, and D.

Figure 5-4. Daily Average Temperature at Sites C, C2, and D



For the reporting period, water temperatures measured at Site C2 more closely resembled water temperatures at Site D than at Site C. Differences in average daily water temperature between Site C and Site C2 varied between 0 and 2°F, and differences in average daily water temperature between Site C2 and Site D varied between 0 and 1°F.

Mann-Whitney U Test analyses of daily average temperature values at Site C, Site C2, and Site D are shown in Table 5-6. Results demonstrate that differences in temperatures during the reporting period are not statistically significant ($p>0.05$).

Table 5-6. Mann-Whitney U Test, Water Temperature at Site C, C2, and Site D

Program Phase	Comparison	p-value	Median Values		
			Site C	Site C2	Site D
Reporting Period	Site C vs. Site C2	0.727	53	54	-
Reporting Period	Site C2 vs. Site D	0.939	-	54	54

A box and whisker plot of the 15-minute and hourly temperatures for Site C and Site D is shown on Figure 5-5. The box represents the 25th through the 75th percentile of data, where 50% of the datapoints are within the box. The center line in the box represents the median and the triangle represents the mean. The lower and upper whiskers represent the 5th and 95th percentile, where 90% of the datapoints are between the whiskers. Outliers from the dataset are shown as points.

Figure 5-5. Reporting Period Water Temperature Data Box and Whisker Plots at Site C and Site D

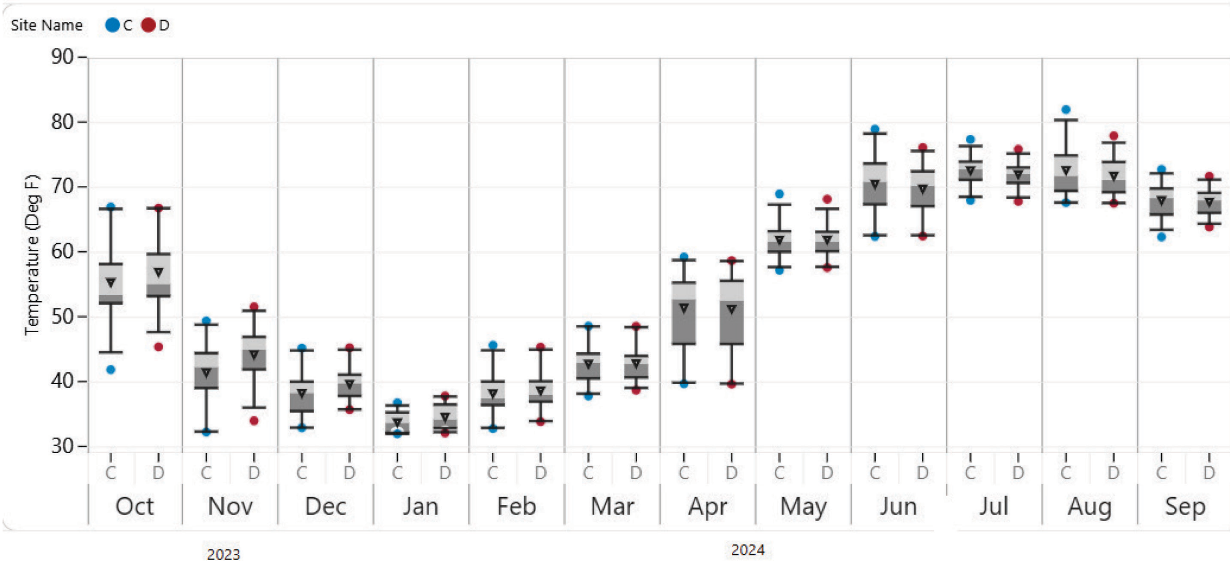


Table 5-7 summarizes the water temperature thresholds for the Root River. The ambient water temperatures are site specific to the Root River at Site C, while the sublethal and acute temperatures are default temperature thresholds for warm small rivers from Wisconsin Administrative Code NR102 (WDNR 2024).

Table 5-7. Monthly Water Temperature Thresholds

Month	Temperature Thresholds (°F)		
	Ambient	Sublethal	Acute
January	33	49	76
February	34	50	76
March	39	52	77
April	47	55	79
May	59	65	82
June	69	76	84
July	74	81	85
August	72	81	84
September	66	73	82
October	55	61	80
November	42	49	77
December	34	49	76

Daily average water temperature exceedances of the ambient, sublethal, and acute water temperature thresholds (Table 5-7) were assessed for Site C and Site D during the reporting period (Table 5-8). The daily average temperature was compared to the monthly temperature threshold and exceedances were summed. For example, if the daily average temperature at Site C exceeded the January ambient temperature threshold on January 3 and January 15, two exceedances were reported.

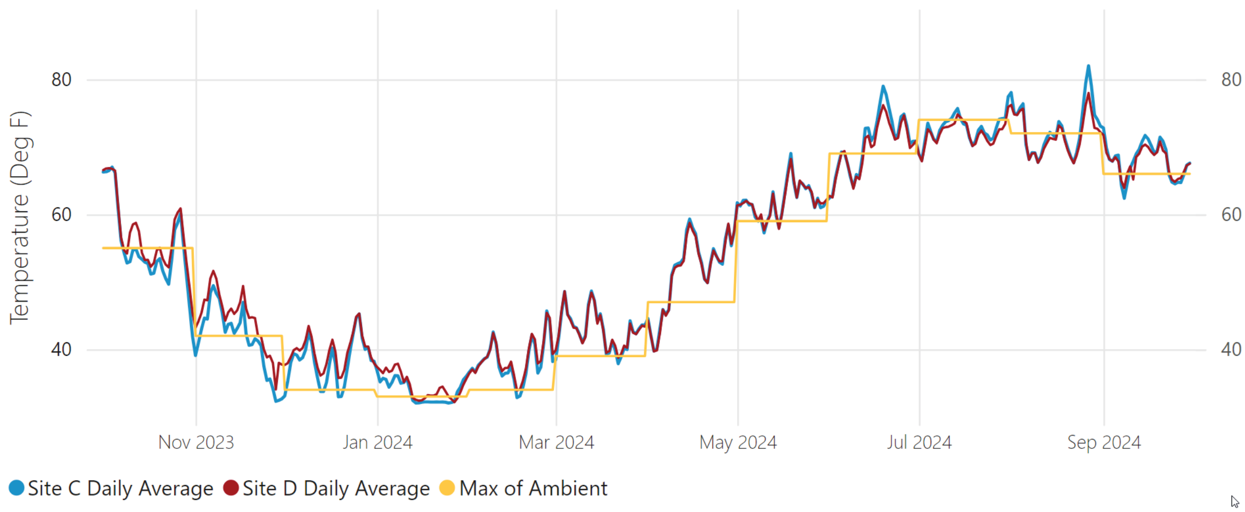
Table 5-8. Summary of Water Temperature Threshold Exceedances at Site C and Site D Using Daily Average Water Temperatures

Month	Site C			Site D		
	Ambient	Sublethal	Acute	Ambient	Sublethal	Acute
2023						
October	11	5	-	17	6	-
November	16	1	-	22	4	-
December	26	-	-	31	-	-
2024						
January	16	-	-	23	-	-
February	27	-	-	28	-	-
March	28	-	-	30	-	-
April	22	8	-	22	8	-
May	27	2	-	28	4	-
June	20	3	-	20	1	-
July	8	-	-	3	-	-
August	15	1	-	14	-	-
September	21	-	-	23	-	-

Note:
"-" indicates that no temperature threshold exceedances were recorded.

A time-based assessment of ambient threshold exceedances each month at Sites C and D is shown on Figure 5-6. Instances where the daily average water temperature is higher than the horizontal line representing the threshold indicate an exceedance. Based on these results, exceedances occurred throughout the month and did not appear to occur more frequently at the beginning or end of any given month. This is consistent with results observed during the pre-diversion period.

Figure 5-6. Reporting Period Daily Average Temperature Comparison with Ambient Threshold



5.1.3 Reporting Period Water Temperature Observations

When assessing the impact of return flow, key themes from the QAPP were considered such as changes in river water temperature upstream and downstream of return flow, seasonal differences, and the spatial extent of temperature.

River water temperatures both upstream and downstream of return flow were slightly warmer than pre-diversion conditions. This aligns with broader reporting of this reporting period year being warmer than an average pre-diversion year. While warmer than average water temperatures were observed in the Root River at all sites during the reporting period, Site A was the only site at which the warmer temperatures were statistically significant compared to pre-diversion water temperatures. Water temperatures at Site B, Site C, and Site D were within statistically similar ranges observed during the pre-diversion period, suggesting that impacts to temperature at Site A did not have a substantial downstream effect.

Seasonal trends along the Root River followed pre-diversion conditions, where water temperature is coldest in December and January and warmest in July and August. Seasonal water temperature trends when comparing Site C and Site D did demonstrate variations. During the reporting period, Site D was 0 to 3°F warmer in the winter and 0 to 1°F cooler in the summer compared to Site C. This is a notable change from most of the pre-diversion period, apart from 2022 during which Site D was similarly cooler in the summer compared to Site C.

This suggests that return flow is cooling the river in summer months and slightly warming the river in winter months. However, because these trends also align with conditions observed in the summer of 2022, the extent to which return flow and natural variation are each impacting water temperatures is not conclusive. This will continue to be assessed in subsequent reporting periods.

The spatial extent of water temperature changes caused by return flow is inconclusive at this stage of the reporting period. There are substantially less reporting period water temperature data compared to the pre-diversion period. Therefore, subsequent years of data collection will increase confidence in the assessment of return flow.

6 Water Quality

During the reporting period, Root River water quality was measured consistent with the QAPP. Water quality was assessed at four sampling locations: Sites A, B, C, and D.

6.1 Data Quality

Water quality data collected as part of the diversion monitoring activities were reviewed quarterly for completeness and accuracy and underwent further quality control at the end of this reporting period. Field data were reviewed to identify and assess outliers caused by potential field equipment malfunctions, inaccurate meter calibration, sampling method errors, or other conditions noted by the field teams.

During the reporting period, 17 turbidity measurements were removed from the dataset. Sixteen of these were from samples collected on July 2, 2024, based on a reported probe malfunction by the field staff. One additional turbidity measurement from March 5, 2024, at Site D was removed as an outlier based on field staff noting either a field equipment malfunction, inaccurate meter calibration, or sampling method error. Laboratory results underwent a similar review, but no data points were removed. Remaining data points outside the expected parameter ranges identified in the QAPP are discussed in the following sections.

6.2 Reporting Period Water Quality

A summary of water quality during the reporting period for Sites A through D is shown in Table 6-1. As part of the QAPP, expected data ranges were established to support the assessment of data quality. The last two columns in Table 6-1 show the number and percent of data points that fell outside of the parameter expected range during the reporting period. Parameters that include data points outside of the QAPP expected range include turbidity, specific conductance, orthophosphate, and total suspended solids (TSS).

Data points outside of the turbidity expected range are greater than the 120 nephelometric turbidity units (NTUs) expected maximum. The values ranged from 123 NTUs to 170 NTUs. For the higher turbidity values, these occurrences may be the result of field water quality meter malfunctions or inaccurate calibrations. In cases where field teams did not note issues with the equipment or field procedures, the turbidity data have remained in the dataset. Some occurrences of high turbidity levels also coincided with precipitation events where temporary increases in turbidity is expected (refer to Section 6.2.8.1). These data remained in the dataset.

Data points outside of the specific conductance and orthophosphate expected ranges are less than the 0.1 milliSiemens per centimeter (mS/cm) specific conductance and 0.01 milligram per liter (mg/L) orthophosphate. The specific conductance expected range was set based on the field probe limits of detection, while the orthophosphate expected range was similarly established based on the anticipated laboratory limit of detection. Specific conductance and orthophosphate results that fall below the expected range minimums do not impact reporting period water quality observations. These data remained in the dataset.

Data points outside the TSS expected range are greater than the 175 mg/L expected maximum. These occurrences were infrequent (n = 2), and they passed quality assurance and quality control procedures by the Wisconsin State Laboratory of Hygiene. These data remained in the dataset.

Table 6-1. Reporting Period Water Quality Summary, Site A through Site D

Parameter	Unit	All Sites (A-D)					
		5th Percentile	Median ± Standard Deviation	95th Percentile	QAPP Expected Range[a]	Data Points Outside of Expected Range	Percent of Data Points Outside of Expected Range (%)
pH	S.U.	7.13	7.71 ± 0.24	7.97	6 to 10	0	0
Dissolved Oxygen	mg/L	4.83	7.30 ± 2.55	12.63	0.01 to 15	0	0
Temperature	deg Celsius	1.40	16.40 ± 7.71	24.00	-5 to 35	0	0
Turbidity	NTU	3.55	13.71 ± 44.59	152.01	0.1 to 120	28	8.16
Specific Conductance	mS/cm	0.40	0.72 ± 0.23	1.19	0.1 to 10	1	0.28
Phosphorus	mg/L	0.07	0.13 ± 0.12	0.44	0.01 to 5	0	0
Orthophosphate	mg/L	0.01	0.05 ± 0.05	0.18	0.01 to 3	5	6.33
Total Nitrogen	mg/L	0.93	3.36 ± 2.64	8.95	0.01 to 15	0	0
Nitrate-Nitrite	mg/L	0.22	1.59 ± 2.51	7.03	0.01 to 15	0	0
Ammonia	mg/L	0.02	0.05 ± 0.25	0.23	0.01 to 3	0	0
TSS	mg/L	7.40	22.60 ± 47.68	148.30	1 to 175	2	2.53
Chlorophyll	µg/L	2.03	6.38 ± 10.97	36.14	0.01 to 360	0	0

Notes:
[a] Post-Return Flow Root River Monitoring Plan and Quality Assurance Project Plan. Jacobs, 2023.
µg/L = microgram(s) per liter
deg Celsius = degree(s) Celsius (°C)
S.U. = standard unit(s)

6.2.1 Root River and CWP Water Quality Comparisons

The CWP prepares monthly discharge monitoring reports (DMR) that summarize water quality results required through the Wisconsin Pollutant Discharge Elimination System (WPDES) permit requirements for return flow. The WPDES permit requires more frequent monitoring of the return flow water quality than is completed in the Root River monitoring QAPP to ensure that the receiving water quality is protected. The differences in the WPDES and QAPP monitoring requires careful review to ensure that proper conclusions are drawn from data comparisons. As noted in Section 4, definitive conclusions are not presented herein because the post-diversion dataset is much smaller than the pre-diversion dataset, however additional complexities of comparing return flow and Root River monitoring data require the following considerations:

- The WPDES permit includes averaging periods such as weekly, monthly and 6-months intervals for non-toxic parameters like phosphorus, dissolved oxygen, and total suspended solids. This approach recognizes that any impact is assessed over a longer period of time, treatment processes have normal variations, and single sample values are not reflective of typical discharge conditions. However, all Root River water quality (less temperature) are discrete samples collected once or twice per month. This difference in data collection frequency must be considered when comparing the datasets. For example, while return flow ammonia concentrations met permit limits for the entire reporting period and were most commonly nondetectable, Root River monitoring showed an increase in ammonia between Sites C and D. A basic comparison might suggest that return flow had an impact, however the single Root River sample was coincidentally collected on one of two days in the month when daily ammonia levels were above nondetection levels but still well within permit limits.
- Various natural environmental factors can impact changes in water quality between sites that are not associated with return flow. For example, total suspended solids at an upstream site can be low if the river has a slow velocity, while a downstream site could have higher values if natural geomorphic features in the river suspend sediment. Similarly, flow conditions, oxygen levels, light, or biological activity between sites can impact phosphorus or nitrogen concentrations.
- Each of the Root River QAPP water quality parameters are not individually critical for assessing river health. Instead, they were included to support a potential future water quality model, similar to the one completed during the Diversion Approval. For example, there is no chlorophyll limit included in the WPDES permit; however, phosphorus, temperature, and nitrogen could influence chlorophyll levels and a model's ability to assess natural or anthropogenic changes. Each water quality parameter is summarized below, though not all are suitable for individually assessing the impacts to the river.

During the reporting period, the CWP met all effluent water quality permit conditions except for a minor exceedance of the Root River 6-month non-growing season phosphorus limit (0.066 mg/L compared to 0.060 mg/L). This exceedance was due to ongoing construction at the CWP that impacted the chemical feed system and effluent filters. However, the CWP effluent was still less than the Root River (and Fox River) phosphorus water quality standard of 0.075 mg/L and the monthly phosphorus limits were met during all months. As additional data is collected during the post-diversion period, a better understanding of the natural variability within the Root River, from return flow, and caused simply by differences in data collection frequency will be achieved. These conditions should be considered when comparing pre- and post-diversion data.

6.2.2 Phosphorus

Median phosphorus levels for growing and non-growing seasons at each site during the reporting period are shown in Table 6-2. Phosphorus levels are color-coded: values below the water quality criterion of 0.075 mg/L are shaded in green, while those exceeding the criterion are shaded in yellow. All median phosphorus levels exceeded the 0.075 mg/L criterion in this reporting period.

Table 6-2. Median Phosphorus Levels During the Reporting Period

Season	All Sites	Site A	Site B	Site C	Site D
Growing Season					
October 2023, May 2024 – September 2024	0.147	0.104	0.258	0.144	0.145
Non-growing Season					
November 2023 – April 2024	0.090	0.078	0.143	0.088	0.086

Throughout the reporting period, all sampling sites recorded higher phosphorus levels during the growing season compared to the non-growing season. Specifically, Site B exhibited the highest phosphorus levels among the sites, whereas Site A had the lowest levels, and Site C was in-between. This pattern aligns with the expectation of a well-mixed flow downstream of the Root River mainstem and Root River Canal confluence at Site C. The elevated phosphorus concentrations at Site B are likely attributed to upstream municipal wastewater discharges. Biological activity within the river may further influence phosphorus levels across all sampling sites.

Phosphorus concentrations of the return flow were measured daily at the CWP. Table 6-3 summarizes the seasonal averages, while monthly averages are shown on Figure 6-1. The seasonal average phosphorus concentrations of the return flow were consistently lower than the water quality criterion and median phosphorus concentrations observed at all Root River locations. Figure 6-1 further illustrates that, on a monthly basis, the average phosphorus concentrations of the return flow were always lower than the monthly median phosphorus concentrations at each Root River sampling site, except for February 2024 at Site A.

Table 6-3. Average CWP Phosphorus Levels During the Reporting Period

Season	CWP Phosphorus (mg/L as P)
Growing Season	
October 2023, May 2024 – September 2024	0.046
Non-growing Season	
November 2023 – April 2024	0.066

Phosphorus levels during the growing season and non-growing season at Sites A through D during the reporting period are shown on Figures 6-1 through 6-5. Observations about the results displayed on each figure are summarized following the figure.

Figure 6-1. Maximum and Minimum Phosphorus Concentrations During the Pre-Diversion Period Compared to Median Phosphorus Concentrations in the Root River and Average Phosphorus Concentration in Return Flow (CWP) for the Reporting Period

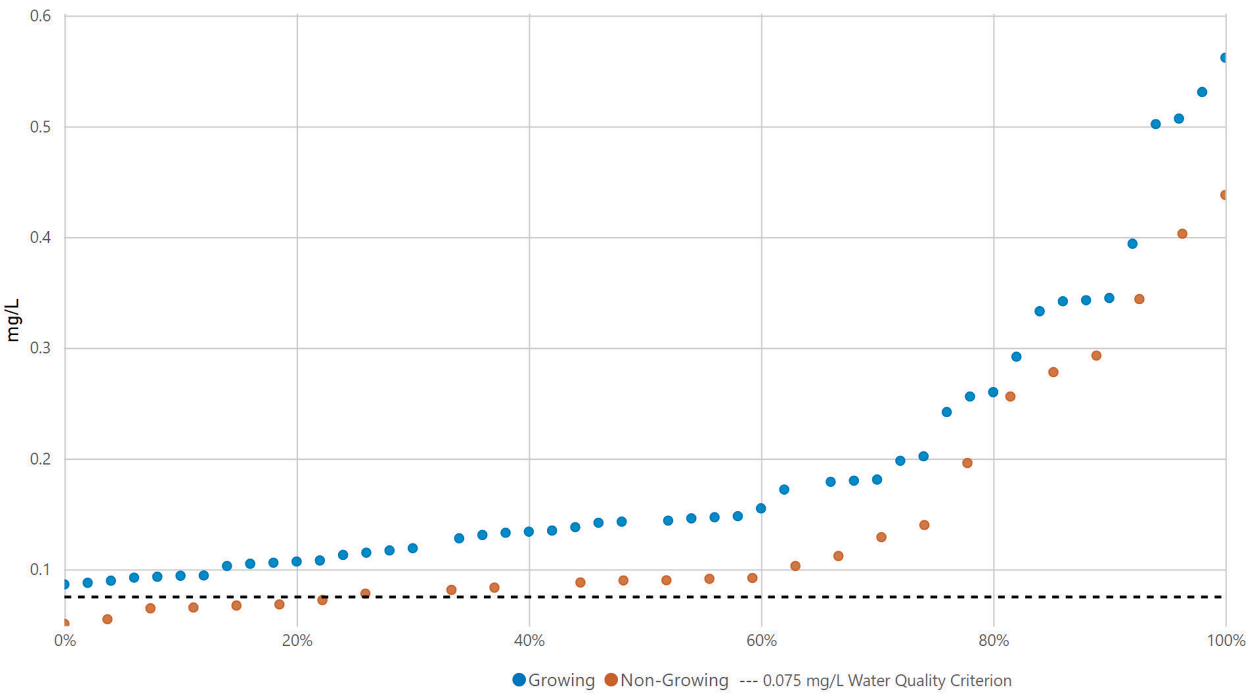
Note: For the months of January to May and November to December, the median reporting period data are based on a single sampling data point. For the months of June to October, data are based on two sampling data points.

6.2.2.1 Observations of Reporting Period Phosphorus Concentrations Compared to Pre-Diversion Period

- The reporting period median monthly concentrations at Site A were within the range of minimum and maximum monthly phosphorus values reported in the pre-diversion period for all months, except April.
- The reporting period median monthly concentrations for Sites B, C, and D were within the range of minimum and maximum monthly phosphorus values reported in the pre-diversion period for all months, except February, March, and May.
- In all cases, the average monthly phosphorus concentrations of the return flow were less than the Root River maximum monthly phosphorus values and were regularly less than the minimum monthly phosphorus values reported in the pre-diversion period.
- Monthly average return flow phosphorus concentrations were lower than Root River concentrations for all months at Sites B, C, and D.
- The phosphorus concentration peaks at downstream Sites C and D have similar patterns from upstream Site B, suggesting that Site B has the greatest impact on Site D.

- Phosphorus levels during the reporting period have remained within the historical range observed prior to the diversion.

Figure 6-2. Reporting Period Phosphorus Levels Cumulative Percentile, Sites A through D, during Growing and Non-Growing Seasons



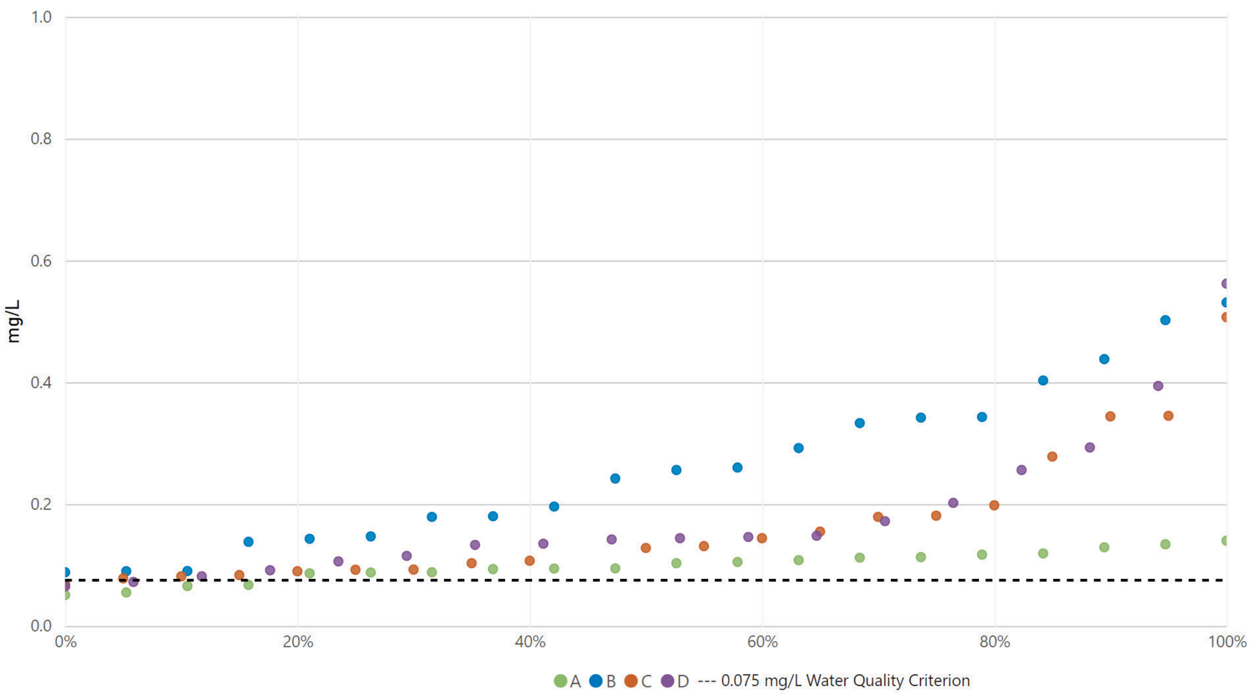
6.2.2.2 Observations of Phosphorus Differences Across Seasons

- In the reporting period, phosphorus concentrations were statistically greater in the growing season compared to the non-growing season (Table 6-4, $p<0.05$), which was similarly observed in the pre-diversion period.
- All samples measured during the growing season exceeded the water quality standard of 0.075 mg/L, whereas 75% of samples measured during the non-growing season exceeded this standard. This is an increase from the pre-diversion period of 90% exceedance during the growing season and 45% during the non-growing season.
- Statistical differences in phosphorus between pre-diversion and reporting period results may be due to the single year of reporting period data and different climate patterns, runoff, biological activity and phosphorus cycling (Table 6-4, $p<0.05$).

Table 6-4. Mann-Whitney U Test, Phosphorus during Growing Season vs. Non-growing Season

Program Phase	Comparison	p-value	Median Values	
			Growing	Non-growing
Pre-Diversion	Growing vs. Non-growing	$< 1 \times 10^{-10}$	0.144	0.090
Reporting Period	Growing vs. Non-growing	4.56×10^{-04}	0.127	0.072
Season	**Comparison**	**p-value**	**Median Values**	
			Pre-Diversion	**Reporting Year**
Growing Season	Pre-Diversion vs. Reporting Period	0.0055	0.127	0.144
Non-Growing Season	Pre-Diversion vs. Reporting Period	0.0021	0.072	0.090

Figure 6-3. Reporting Period Phosphorus Levels Cumulative Percentile, Sites A through D



6.2.2.3 Observations of Phosphorus Differences Across Sampling Sites

- No statistically significant difference was observed in phosphorus concentrations between Site C (0.13 mg/L) and Site D (0.14 mg/L) during the reporting period (Table 6-5, $p>0.05$).
- Phosphorus concentrations showed an increase from Site A to Site B and Site C, a decrease from Site B to Site C, and no significant change from Site C to Site D.
- The results of the reporting period are consistent with the pre-diversion period, indicating a consistent trend of high phosphorus levels at Site B mix with lower levels at Site A, resulting in an intermediate concentration at Site C.
- Statistically significant differences in phosphorus concentrations ($p<0.05$) were observed across various sites: between Sites A and B, where levels increased from 0.10 mg/L to 0.25 mg/L;

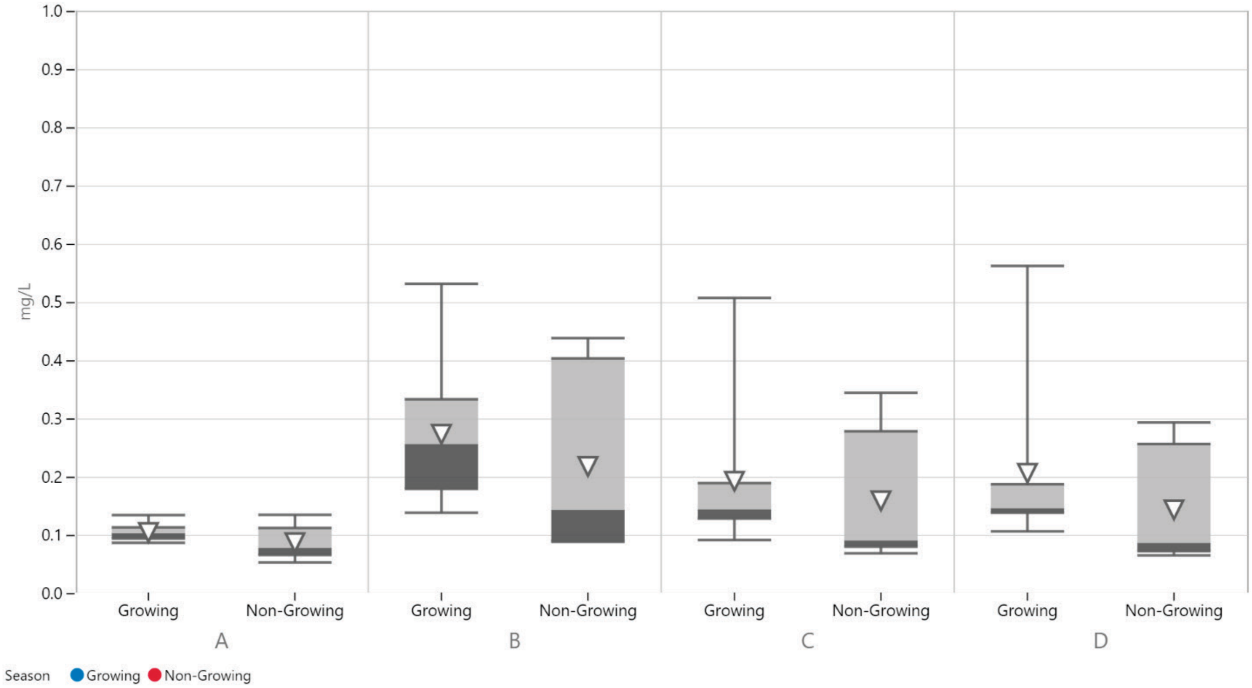
between Sites B and C, where levels decreased from 0.25 mg/L to 0.13 mg/L; and between Sites A and C, where levels increased from 0.10 mg/L to 0.13 mg/L.

- Site B saw the greatest increase in median phosphorus concentration between the pre-diversion period and the reporting period, with a median value increase of 53.7%. In comparison, Sites A, C, and D saw increases of 24.5%, 17.4%, and 28.8%, respectively.

Table 6-5. Mann-Whitney U Test, Phosphorus Comparison Across Sampling Sites

Program Phase	Comparison	p-value	Median Values	
			Site A	Site B
Pre-Diversion	Site A vs Site B	$< 1 \times 10^{-10}$	0.079	0.162
Reporting Period	Site A vs Site B	1.69×10^{-05}	0.099	0.249
			Site A	Site C
Pre-Diversion	Site A vs Site C	1.18×10^{-05}	0.079	0.109
Reporting Period	Site A vs Site C	3.24×10^{-02}	0.099	0.128
			Site B	Site C
Pre-Diversion	Site B vs Site C	1.47×10^{-07}	0.162	0.109
Reporting Period	Site B vs Site C	1.95×10^{-02}	0.249	0.128
			Site C	Site D
Pre-Diversion	Site C vs Site D	0.604	0.109	0.111
Reporting Period	Site C vs Site D	0.612	0.128	0.143

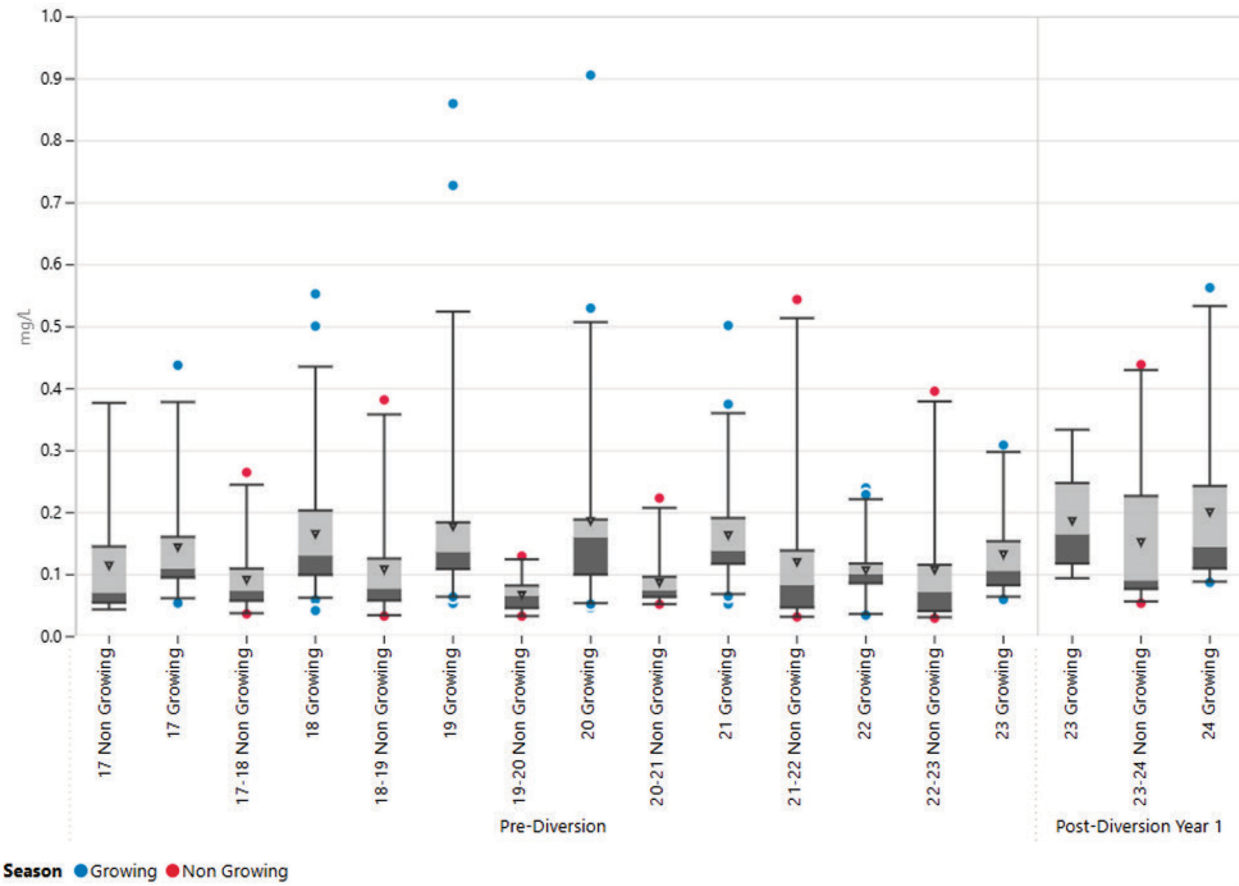
Figure 6-4. Reporting Period Phosphorus Levels Box and Whisker Plot, Sites A through D



6.2.2.4 Observations of Phosphorus Differences Across Seasons and Sampling Sites

- Higher phosphorus levels at Site B compared to all other sampling sites was observed in the growing and non-growing season, which may be due to wastewater discharges upstream of the sampling site.
- Downstream of the confluence of the Root River mainstem and the Canal, at Site C and Site D, phosphorus levels demonstrate a mixed flow from phosphorus levels at Site A and Site B.
- Site A data show the lowest variability in phosphorus levels among the four sites in both the growing and non-growing season.
- Greater phosphorus concentrations in the growing season compared to the non-growing season were observed at all sites.
- The trends observed in the reporting period between the growing and non-growing season across locations are consistent with the pre-diversion period.

Figure 6-5. Season and Year Phosphorus Levels Box and Whisker Plot – Sites A through D



Note: Year is indicated by last two numbers. For example, 2017 is labeled as "17."

6.2.2.5 Observations of Phosphorus Differences Across Seasons Over Time

- Annual trends during the growing and non-growing seasons show consistent elevated and more variable phosphorus levels during the growing season, except in 2022, which was a particularly warm year in the Root River.

6.2.3 Field pH

Median pH levels for growing and non-growing seasons at each site during the reporting period are shown in Table 6-6. A relative color scale from yellow to green for increasing median pH levels is used to visually compare the season and sampling site.

Table 6-6. Median pH Levels for Growing and Non-growing Seasons

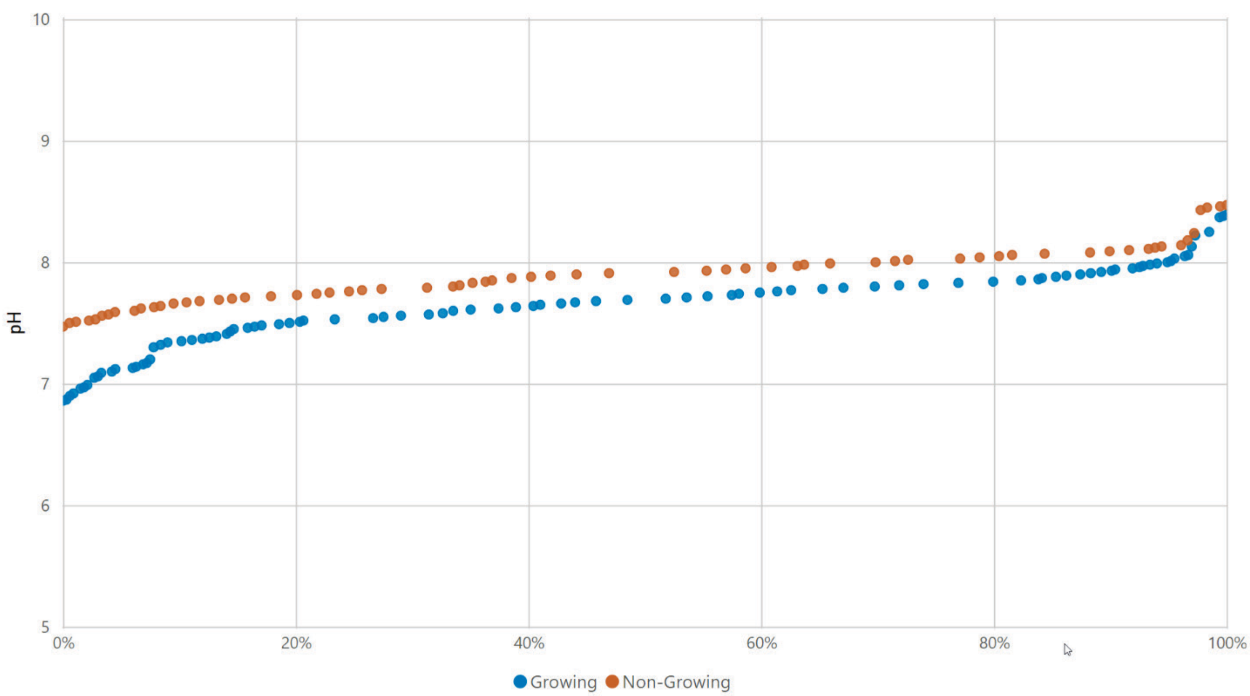
Season	All Sites	Site A	Site B	Site C	Site D
Growing Season					
October 2023 – September 2024	7.64	7.59	7.66	7.63	7.72
Non-growing Season					
October 2023 – September 2024	7.80	7.88	7.65	7.86	7.80

The results demonstrate that median pH levels at the sampling sites typically are between 7.6 and 7.8, and in the growing season, slightly higher pH levels are observed at downstream sites compared to upstream.

To evaluate the changes between the pre-diversion and reporting periods, the median monthly pH levels were compared. The median monthly pH levels during the reporting period were consistently within the range of the minimum and maximum values recorded in the pre-diversion period. This indicates that pH levels observed in the reporting period are within the historical variability observed prior to the diversion.

Field pH measurements during the growing season and non-growing season at Sites A through D during the reporting period are shown on Figures 6-6 through 6-9. Observations about the results illustrated on each figure are summarized following the figure.

Figure 6-6. Reporting Period Field pH Cumulative Percentile by Season



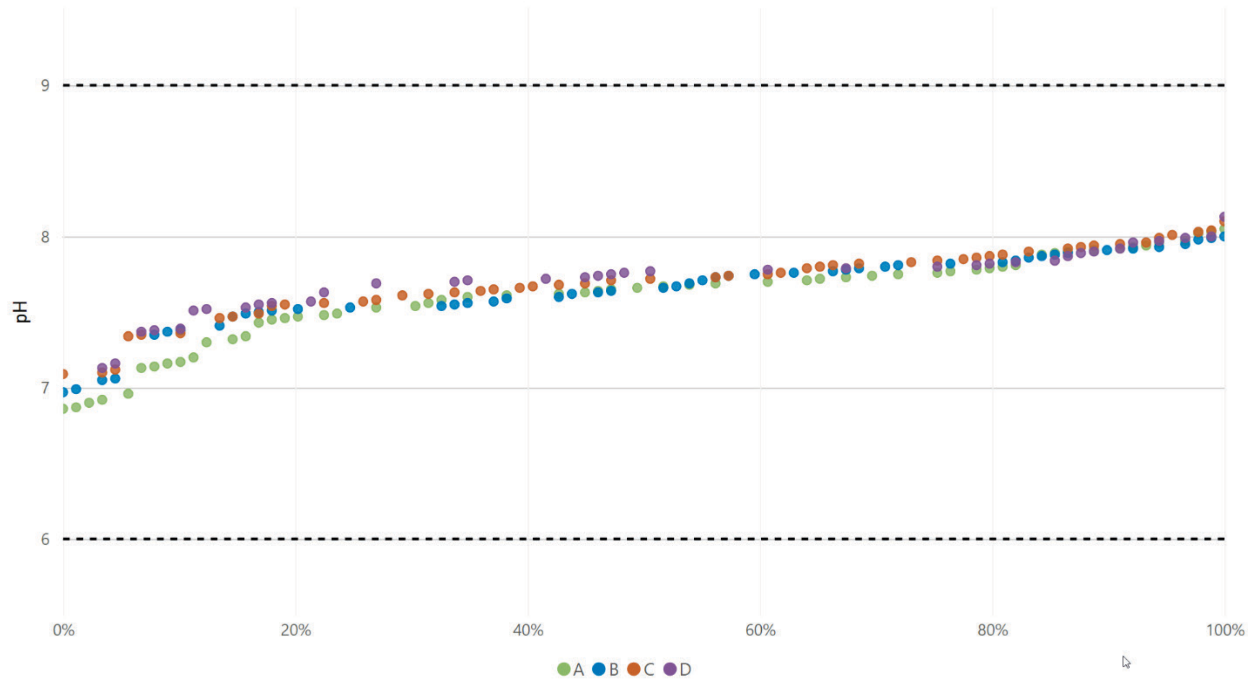
6.2.3.1 Observations of pH Differences Across Seasons

- In the reporting period, pH was lower in the growing season compared to the non-growing season. The trend is consistent with the pre-diversion period.
- All pH measurements fell within the water quality standard minimum of 6 and maximum of 9.
- Similarly to pre-diversion conditions, biological activity in the river during growing and non-growing seasons also may influence the observed pH levels.
- Statistical differences in pH between pre-diversion and reporting period results may be from the single year of reporting period data and different climate patterns, runoff, biological activity, and water chemistry (Table 6-7, $p<0.05$).

Table 6-7. Mann-Whitney U Test, pH Seasonality during the Pre-Diversion vs Reporting Periods

Season	Comparison	p-value	Median Values	
			Pre-Diversion	Reporting Year
Growing Season	Pre-Diversion vs. Reporting Period	$< 1 \times 10^{-10}$	7.77	7.64
Non-Growing Season	Pre-Diversion vs. Reporting Period	7.31×10^{-03}	7.86	7.80

Figure 6-7. Reporting Period Field pH Cumulative Percentile for Sites A through D



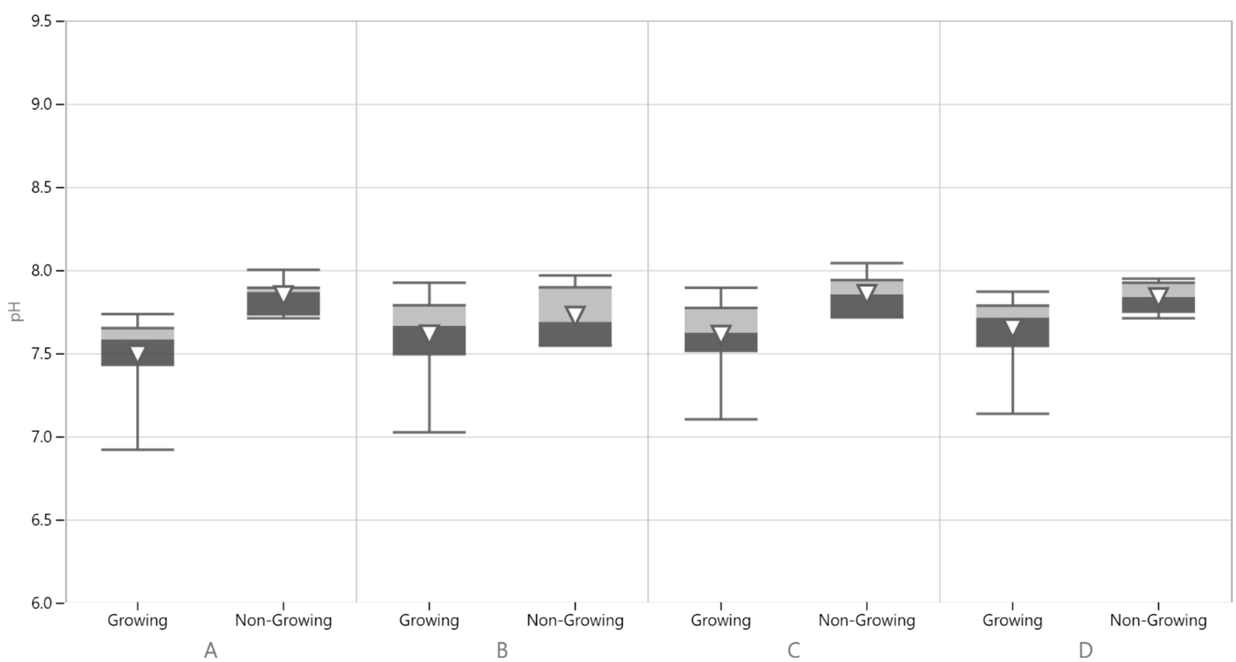
6.2.3.2 Observations of pH Differences Across Sampling Sites

- All pH measurements fell within the water quality standard minimum of 6 and maximum of 9.
- During the reporting period, no statistically significant difference was observed in pH levels between Sites A and B, and Sites B and C (Table 6-8, p>0.05). This differs from pre-diversion conditions where these sites had statistical differences (p<0.05).
- Differences between Sites C and D were statistically significant (p<0.05) during the single year reporting period, whereas they were not during the pre-diversion conditions.
- Unlike other water quality parameters, pH levels do not reflect an average of Sites A and B. For most of the dataset, pH Levels at Sites A and B are slightly lower compared to Sites C and D.

Table 6-8. Mann-Whitney U Test, pH Comparison Across Sampling Sites

Program Phase	Comparison	p-value	Median Values	
			Site A	Site B
Pre-Diversion	Site A vs. Site B	0.006	7.72	7.75
Reporting Period	Site A vs. Site B	0.499	7.67	7.66
			Site A	Site C
Pre-Diversion	Site A vs. Site C	$< 1 \times 10^{-10}$	7.72	7.84
Reporting Period	Site A vs. Site C	4.72×10^{-02}	7.67	7.72
			Site B	Site C
Pre-Diversion	Site B vs. Site C	2.52×10^{-07}	7.75	7.84
Reporting Period	Site B vs. Site C	0.163	7.66	7.72
			Site C	Site D
Pre-Diversion	Site C vs. Site D	0.478	7.84	7.86
Reporting Period	Site C vs. Site D	0.016	7.72	7.77

Figure 6-8. Reporting Period Field pH Box and Whisker Plot by Site and Growing Season

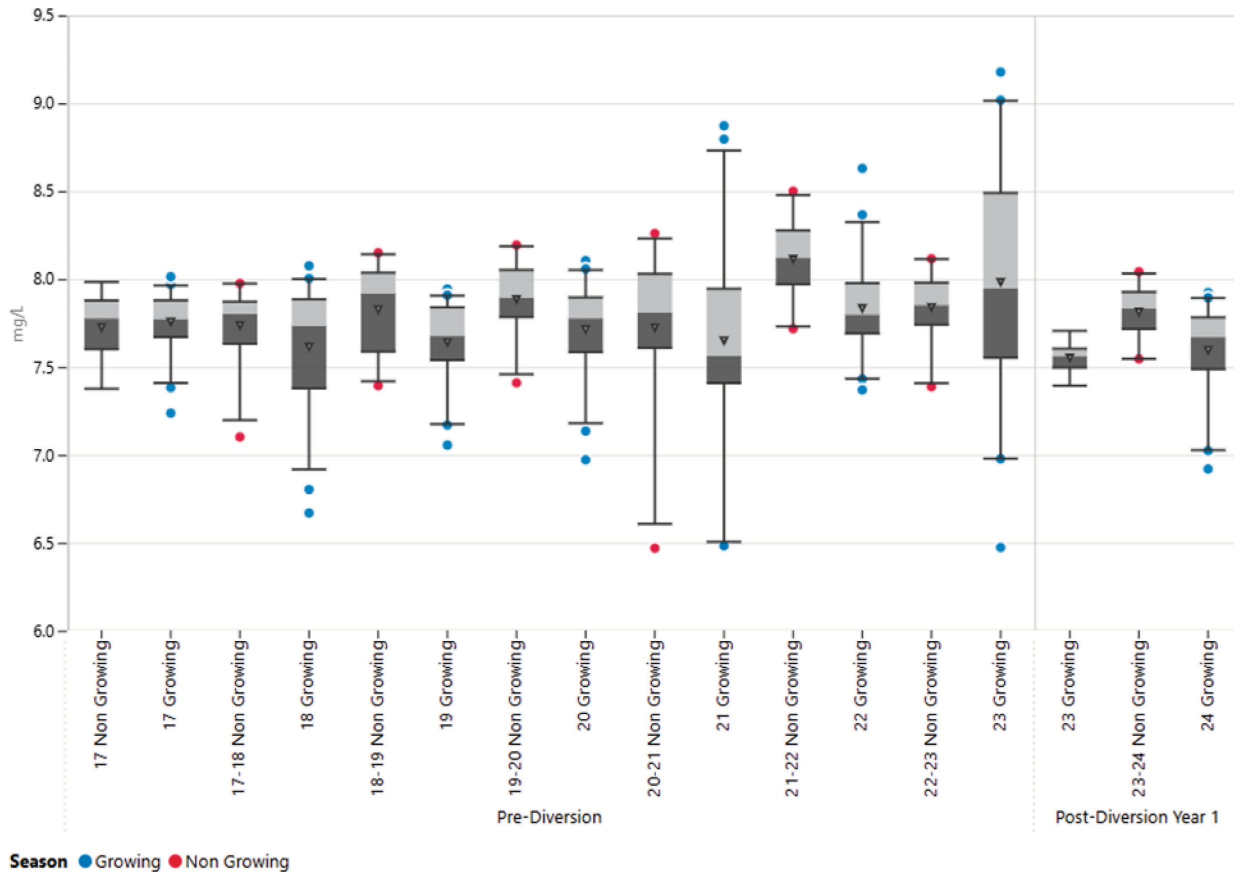


6.2.3.3 Observations of pH Differences Across Seasons and Sampling Sites

- For all sites, the average pH is slightly higher during the non-growing season compared to the growing season. This may be caused by fertilizer applications increasing soil acidity and subsequent soil runoff during the growing season.
- For all sites, greater variability in pH levels is observed during the growing season.

- Site D data show the lowest variability in pH levels among the four sites.
- The trends observed in the reporting period across the locations in the growing and non-growing season are consistent with the pre-diversion period.

Figure 6-9. Season and Year Field pH Box and Whisker Plot for Sites A through D



Note: Year is indicated by last two numbers. For example, 2017 is labeled as "17."

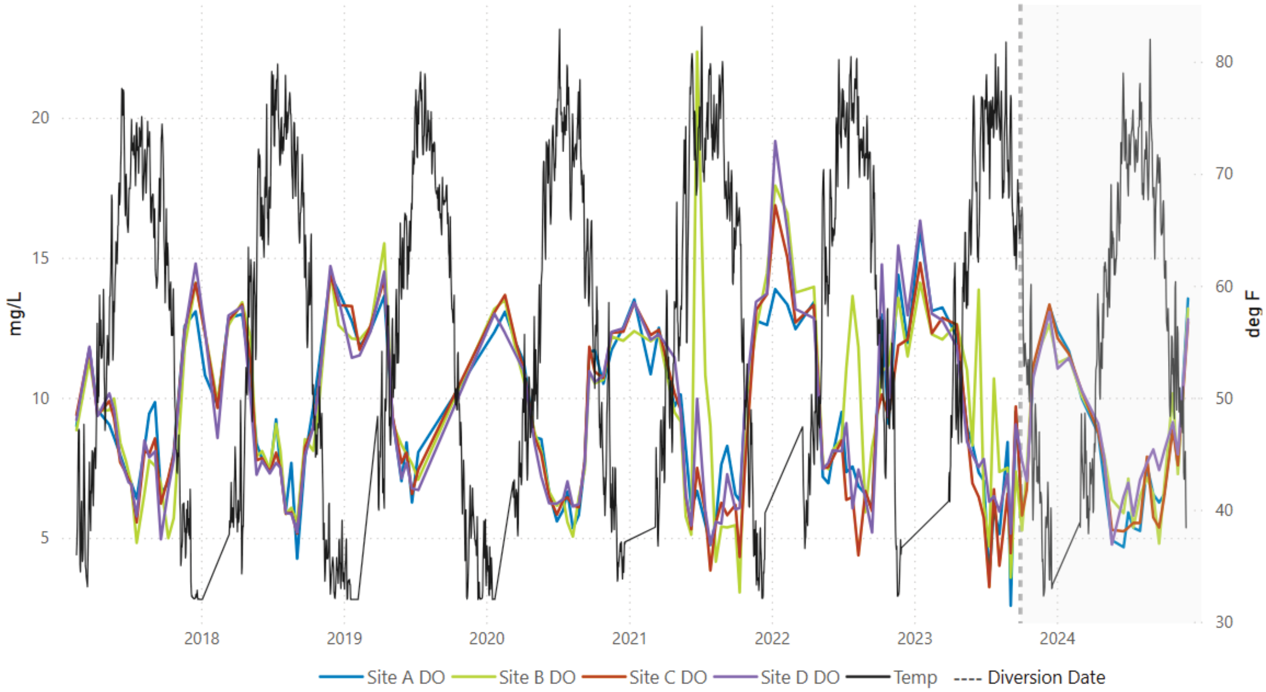
6.2.3.4 Observations of pH Differences Across Seasons Over Time

- Annual trends during the growing and non-growing seasons show consistently higher pH levels during the non-growing season.
- Reporting year pH ranges were within the variation observed during pre-diversion monitoring.

6.2.4 Field Dissolved Oxygen

Field dissolved oxygen measurements during the growing and non-growing seasons at Sites A through D during the reporting period are shown on Figures 6-10 and 6-11. Observations about the results illustrated on each figure are summarized following the figure.

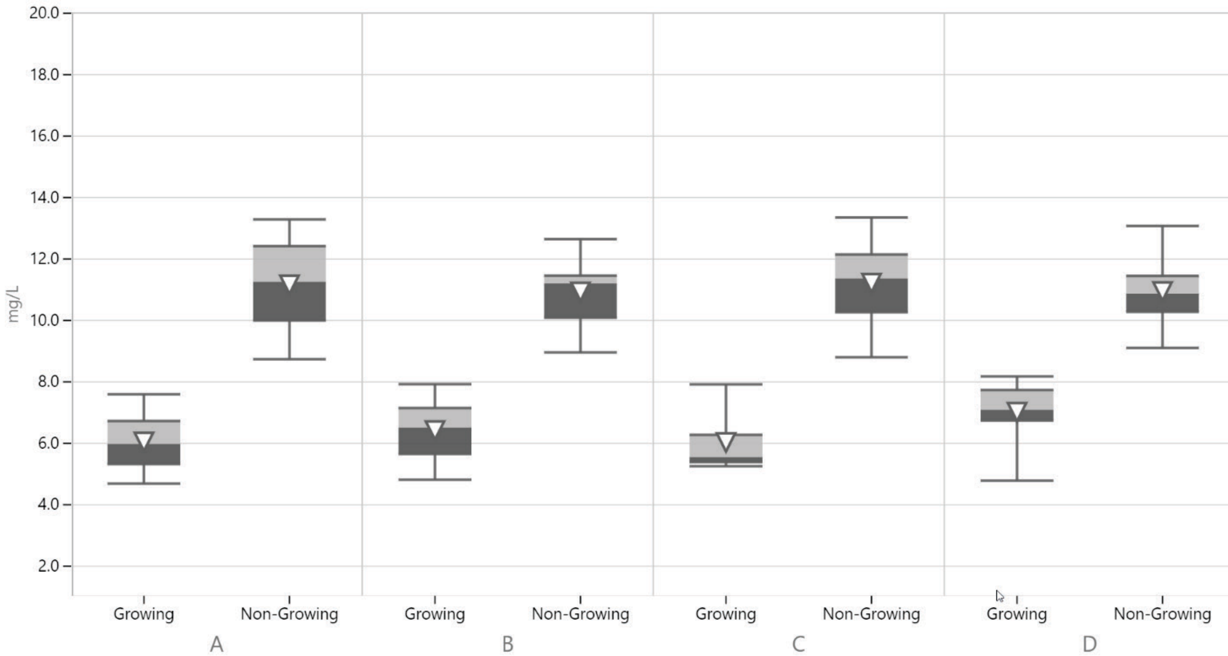
Figure 6-10. Field Dissolved Oxygen for Sites A through D



6.2.4.1 Observations of Dissolved Oxygen Differences Across Sampling Sites Over Time

- Median dissolved oxygen levels were lower in the reporting period at all sites compared to pre-diversion period levels: 19.7% at Site A, 20.7% at Site B, 14.6% at Site C, and the lowest decrease of 4.9% at Site D. As reported in Section 5, average and median temperatures during the reporting period were consistent with or slightly higher than those in the pre-diversion period at all sites. Warmer temperatures can reduce the solubility of oxygen in water and could have been a contributing factor to lower dissolved oxygen levels during the single-year reporting period.
- Additional contributing factors could include higher nutrient concentrations at Site B and low-flow conditions during the year. These factors can increase biological activity and organic matter decomposition, further depleting dissolved oxygen levels.

Figure 6-11. Reporting Period Field Dissolved Oxygen Box and Whisker Plot by Site and Season



6.2.4.2 Observations of Dissolved Oxygen Differences Across Seasons and Sampling Sites

- Despite the overall lower dissolved oxygen levels between the pre-diversion period and the reporting period between Sites C and D, there is a statistically significant increase in dissolved oxygen within the reporting period (Table 6-9, $p<0.05$). This trend was not observed in the pre-diversion period.
- There is no statistical change in dissolved oxygen between Sites A and B, Sites A and C, or Sites B and C (Table 6-9, $p>0.05$).
- The same between pre-diversion and reporting period conditions for all locations, dissolved oxygen had a statistically significant decrease between the growing and non-growing season (Table 6-10, $p<0.05$).
- Dissolved oxygen levels and variability are similar across the sampling sites between growing and non-growing season periods.
- Most dissolved oxygen measurements are greater than the minimum water quality standard of 5 mg/L for all sampling sites: 233 of the total 254 measurements (92%) were >5 mg/L.

Table 6-9. Mann-Whitney U Test, Dissolved Oxygen Comparison Across Sampling Sites

Program Phase	Comparison	p-value	Median Values	
			Site A	Site B
Pre-Diversion	Site A vs. Site B	0.372	8.61	9.06
Reporting Period	Site A vs. Site B	0.329	6.90	7.81
			Site A	**Site C**
Pre-Diversion	Site A vs. Site C	0.087	8.61	8.08
Reporting Period	Site A vs. Site C	0.961	6.90	6.90
			Site B	**Site C**
Pre-Diversion	Site B vs. Site C	0.018	9.06	8.08
Reporting Period	Site B vs. Site C	0.249	7.81	6.90
			Site C	**Site D**
Pre-Diversion	Site C vs. Site D	0.533	8.08	8.14
Reporting Period	Site C vs. Site D	0.003	6.90	7.74

Table 6-10. Mann-Whitney U Test, Dissolved Oxygen during Growing vs. Non-growing Season

Program Phase	Comparison	p-value	Median Values	
			Growing	Non-growing
Pre-Diversion	Growing vs. Non-growing	$< 1 \times 10^{-10}$	7.96	12.84
Reporting Period	Growing vs. Non-growing	$< 1 \times 10^{-10}$	6.94	11.44

6.2.5 Total Suspended Solids

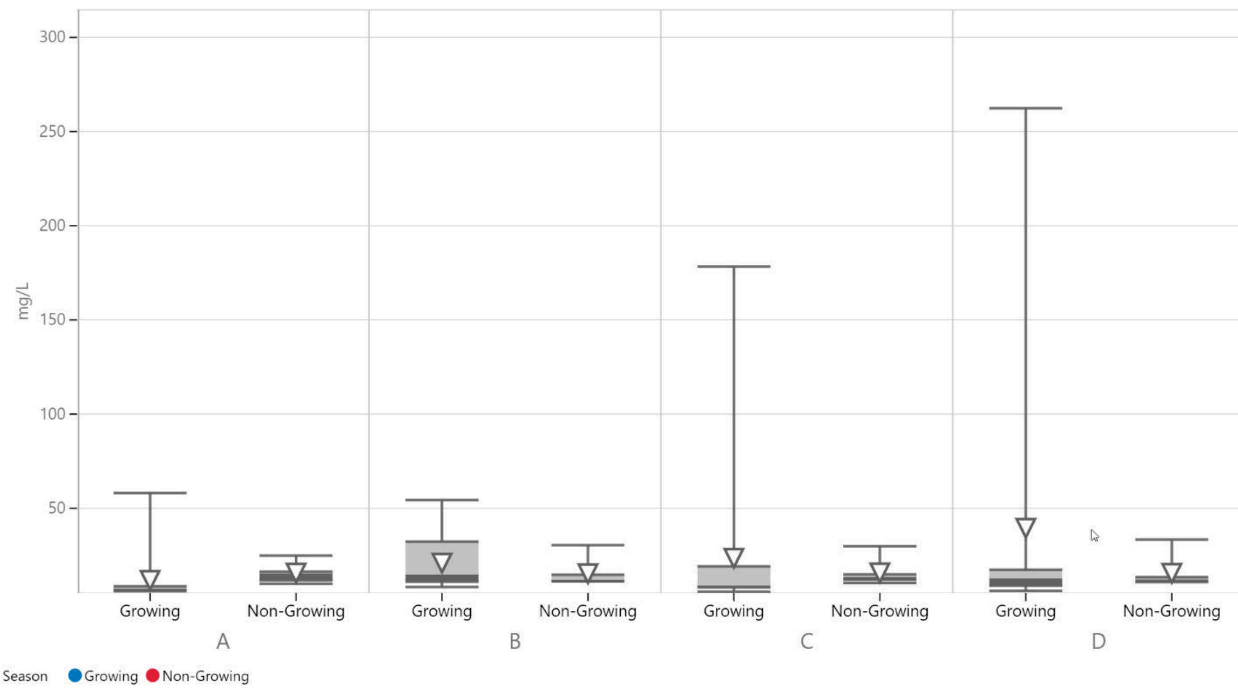
Median TSS levels for growing and non-growing seasons at each sampling site during the reporting period are shown in Table 6-11.

Table 6-11. Reporting Period Median Total Suspended Solids Levels by Site and Season

Season	Site A	Site B	Site C	Site D
Growing Season	14.7 mg/L	38.6 mg/L	20.0 mg/L	36.1 mg/L
Non-growing Season	26.2 mg/L	16.9 mg/L	20.0 mg/L	12.4 mg/L

TSS measurements during the growing and non-growing season at Sites A through D for all years during the reporting period are shown on Figure 6-12. Observations about the results displayed on each figure are summarized following the figure.

Figure 6-12. Reporting Period Total Suspended Solids Box and Whisker Plot by Site and Season



6.2.5.1 Observations of Total Suspended Solids Across Seasons and Sampling Sites

- There is no numeric water quality standard for TSS. However, Total Maximum Daily Loads in Wisconsin have used in-stream targets ranging between 12 mg/L and 26 mg/L. During the growing season, 47% (24 out of 51) of all TSS measurements were less than 26 mg/L. During the non-growing season, 71% (20 out of 28) of all TSS measurements were less than 26 mg/L.
- Only two data points were outside the expected range of 1 to 175 mg/L. These outliers are believed to result from acute environmental events such as water disturbances from precipitation, bank erosion, or disturbance of the riverbed by the sampling team.
- There was no statistically significant difference in TSS between the pre-diversion period and the reporting period. This trend is consistent during both the growing and non-growing seasons across all locations (Table 6-12, p>0.05).
- Within the reporting period, TSS concentrations between Site C to Site D were not statistically different, consistent with the pre-diversion period (Table 6-13, p>0.05).
- TSS concentrations were statistically greater in the growing season compared to the non-growing season in the reporting period, consistent with the pre-diversion period (Table 6-14, p>0.05).

Table 6-12. Mann-Whitney U Test, Total Suspended Solids Seasonality Across Sampling Sites during the Pre-Diversion vs Reporting Periods

Site	Season	Comparison	p-value	Median Values	
				Pre-Diversion	Reporting Period [a]
A	Growing Season	Pre-Diversion vs. Reporting Period	0.366	17.8	14.7
B	Growing Season	Pre-Diversion vs. Reporting Period	0.363	36.5	38.6

Site	Season	Comparison	p-value	Median Values	
				Pre-Diversion	Reporting Period [a]
C	Growing Season	Pre-Diversion vs. Reporting Period	0.868	24.0	20.0
D	Growing Season	Pre-Diversion vs. Reporting Period	0.094	26.2	36.1
A	Non-growing Season	Pre-Diversion vs. Reporting Period	0.467	14.8	26.2
B	Non-growing Season	Pre-Diversion vs. Reporting Period	0.935	16.2	16.9
C	Non-growing Season	Pre-Diversion vs. Reporting Period	0.141	13.3	20.0
D	Non-growing Season	Pre-Diversion vs. Reporting Period	0.513	13.0	12.4

Note:

[a] Reporting Period is Post Diversion Year 1 between October 1, 2023, and September 30, 2024.

Table 6-13. Mann-Whitney U Test, Total Suspended Solids Comparison Across Sampling Sites

Program Phase	Comparison	p-value	Median Values	
			Site A	Site B
Pre-Diversion	Site A vs. Site B	5.72×10^{-05}	17.50	29.50
Reporting Period	Site A vs. Site B	1.55×10^{-02}	19.20	33.30
			Site A	Site C
Pre-Diversion	Site A vs. Site C	0.213	17.50	22.30
Reporting Period	Site A vs. Site C	0.303	19.20	20.00
			Site B	Site C
Pre-Diversion	Site B vs. Site C	0.002	29.50	22.30
Reporting Period	Site B vs. Site C	0.049	33.30	20.00
			Site C	Site D
Pre-Diversion	Site C vs. Site D	0.894	22.30	21.00
Reporting Period	Site C vs. Site D	0.317	20.00	27.25

Table 6-14. Mann-Whitney U Test, Total Suspended Solids Growing vs Non-Growing Season

Program Phase	Comparison	p-value	Median Values	
			Growing	Non-growing
Pre-Diversion	Growing vs. Non-growing	$< 1 \times 10^{-10}$	24.35	12.20
Reporting Period	Growing vs. Non-growing	1.89×10^{-03}	27.10	16.20

6.2.6 E. coli

Return flow *E. coli* levels were measured by the CWP once per week during the disinfection period (May through September 2024) of the reporting period (Table 6-15). Root River monitoring was conducted at Sites C and D (Table 6-15).

Table 6-15. Average Return Flow and Root River E. coli Levels During the Reporting Period

Month	Return Flow (CFU/100 mL)	Site C (CFU/100 mL)	Site D (CFU/100 mL)
October 2023	-	14,136	1,086
November 2023	-	41	171
December 2023	-	171	135
January 2024	-	41	52
February 2024	-	144	195
March 2024	-	934	1,054
April 2024	-	74	41
May 2024	<1	5,813	7,535
June 2024	2	488	432
July 2024	<1	408	158
August 2024	<1	305	279
September 2024	<1	825	256

Note:
CFU/100 mL = colony-forming units per 100 milliliters

6.2.6.1 Observations of E. coli

- There is significant variability in *E. coli* within the Root River between Sites C and D, where both sites follow similar trends.
- For 7 out of the 12 months, and all disinfection season months, *E. coli* concentrations decreased from Site C to Site D.
- Return flow consistently measured significantly lower *E. coli* counts (2 to 3 orders of magnitude) compared to Sites C and D.
- During May 2024 (within the disinfection season) when return flow had an average count less than 1, *E. coli* increased between sites C and D. However, during October 2023 (within the non-disinfection season) *E. coli* decreased by an order of magnitude. These trends demonstrate the variability and challenges with bacteria monitoring within natural waters.

6.2.7 Chlorides

Return flow chloride levels were measured by the CWP on five consecutive days each month of the reporting period consistent with permit requirements. Single-day monthly chloride monitoring was completed in the Root River at Sites C and D consistent with the QAPP (Table 6-16).

Table 6-16. Return Flow and Root River Chloride Levels During the Reporting Period

Month	Return Flow (mg/L)	Site C (mg/L)	Site D (mg/L)
October 2023	494	140	249
November 2023	420	129	173
December 2023	413	130	160
January 2024	395	124	145
February 2024	509	110	127
March 2024	447	149	157
April 2024	398	118	128
May 2024	432	51	61
June 2024	372	70	77
July 2024	363	93	138
August 2024	368	98	162
September 2024	359	139	239

6.2.7.1 Observations of Chlorides

- All Root River chloride levels (above and below return flow) were well below water quality standards (chronic criteria = 395 mg/L).
- The increase in chloride concentrations between sites C and D were greatest (October and November 2023, July to September 2024) when the Root River was experiencing low flows (Table 2-1).

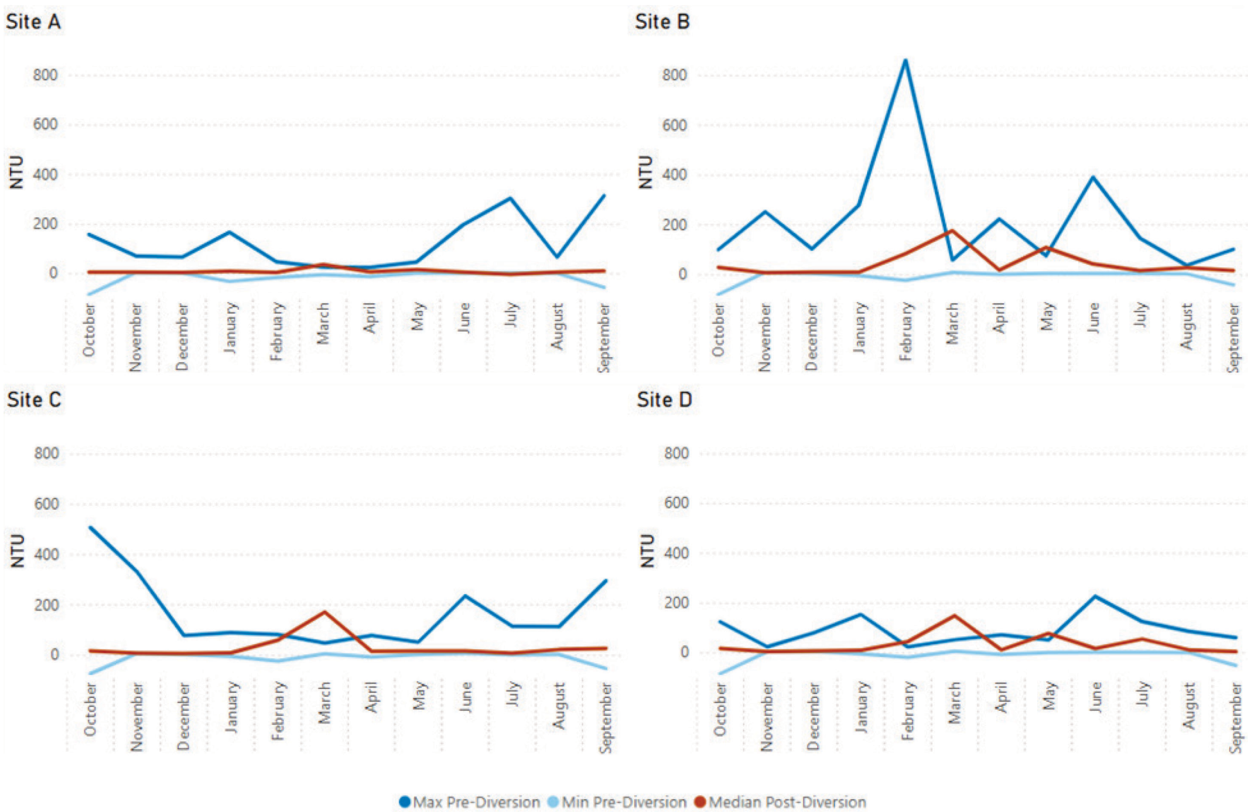
6.2.8 Other Water Quality Parameters

Graphical summaries of additional parameters collected as part of the QAPP are included in the following subsections. These include turbidity (Figure 6-13), specific conductance (Figure 6-14), orthophosphate (Figure 6-15), total nitrogen (Figure 6-16), nitrate-nitrite (Figure 6-17), ammonia (Figure 6-18), and chlorophyll (Figure 6-19). General observations also are summarized following each figure; however, definitive conclusions are not theorized because only a single year of post-diversion sampling has been completed, during which some months had just one or two values (refer also to Section 6.2.1).

6.2.8.1 Turbidity

Figure 6-13 compares the maximum and minimum turbidity readings during the pre-diversion period with the median turbidity results from the reporting period.

Figure 6-13. Maximum and Minimum Turbidity During the Pre-Diversion Period Compared to Median Turbidity Concentrations in the Root River for the First Year of the Reporting Period



Note: For the months of January to May and November to December, the median reporting period data are based on a single sampling data point. For the months of June to October, data are based on two sampling data points.

Turbidity Observations

- Upstream peaks in turbidity are similarly reflected in downstream locations during the reporting period.
- In March of 2024, the median reporting period turbidity at all sites exceeded the pre-diversion maximum. Sampling in that month occurred on March 5, 2024, and followed a rainfall event on that day in which the peak gauge height increased 4.00 feet from the previous day (March 4, 2024)[8] and the Hales Corners/Whitnall Park/Boerner Botanical Gardens National Oceanic and Atmospheric Administration station recorded a rainfall accumulation of 1.16 inches[9].
- In May of 2024, the median reporting period turbidity at Sites B and D exceeded the pre-diversion maximum. A rainfall event also preceded the May 21, 2024, sampling with 0.52 inch of rainfall recorded on May 20, 2024, and 0.26 inch on May 21, 2024[9].
- All other median monthly turbidity values for all sites remained within historical range observed in the pre-diversion period.

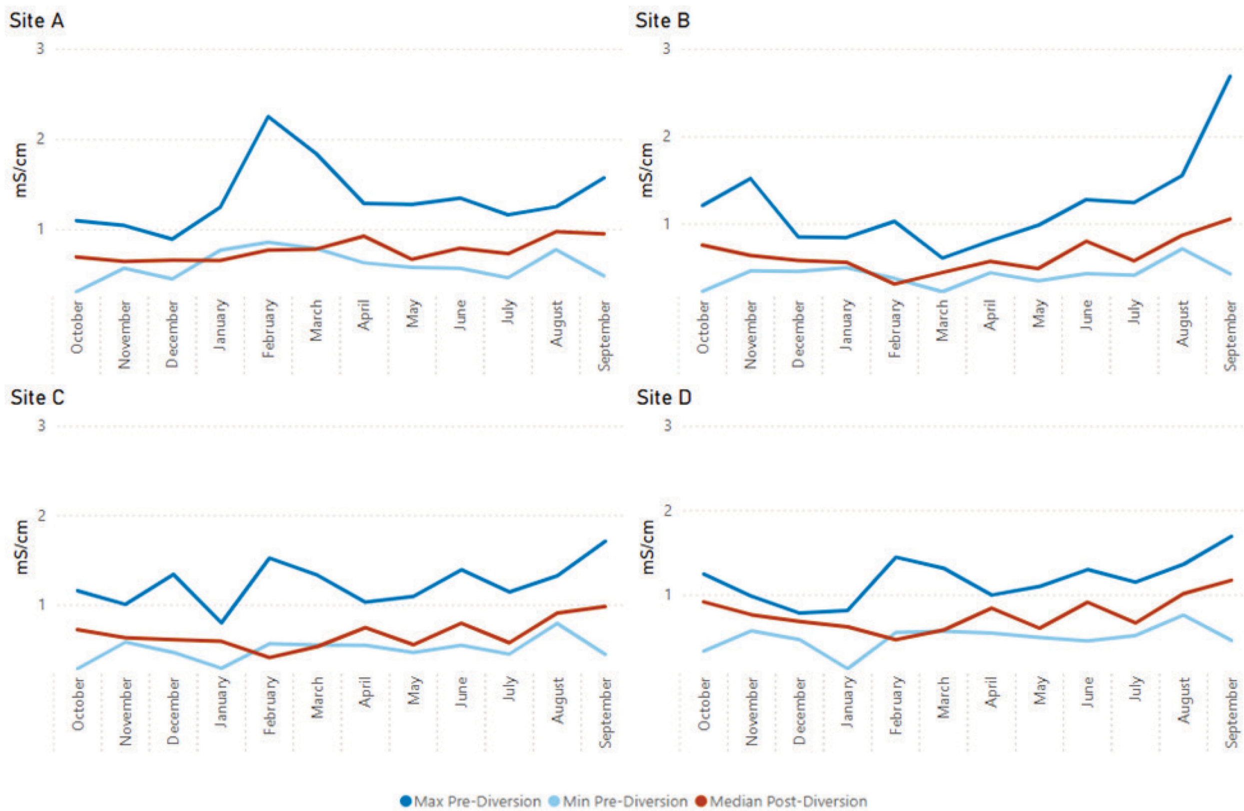
[8] https://waterdata.usgs.gov/monitoring-location/04087234/#dataTypeId=continuous-00065-0&period=P7D&showMedian=false

[9] https://www.weather.gov/wrh/Climate?wfo=mkx

6.2.8.2 Specific Conductance

Figure 6-14 compares the maximum and minimum specific conductance readings during the pre-diversion period with the median specific conductance results from the reporting period.

Figure 6-14. Maximum and Minimum Specific Conductance During the Pre-Diversion Period Compared to Median Specific Conductance Concentrations in the Root River for the First Year of the Reporting Period



Note: For the months of January to May and November to December, the median reporting period data are based on a single sampling data point. For the months of June to October, data are based on two sampling data points.

Specific Conductance Observations

- Specific conductance at all locations and in each month in the reporting period remained below the maximum values and generally fell within the observed ranges from the pre-diversion period.

6.2.8.3 Orthophosphate

Figure 6-15 compares the maximum and minimum orthophosphate results during the pre-diversion period with the median orthophosphate results from the reporting period.

Figure 6-15. Maximum and Minimum Orthophosphate During the Pre-Diversion Period Compared to Median Orthophosphate Concentrations in the Root River for the First Year of the Reporting Period

Note: For the months of January to May and November to December, the median reporting period data are based on a single sampling data point. For the months of June to October, data are based on two sampling data points.

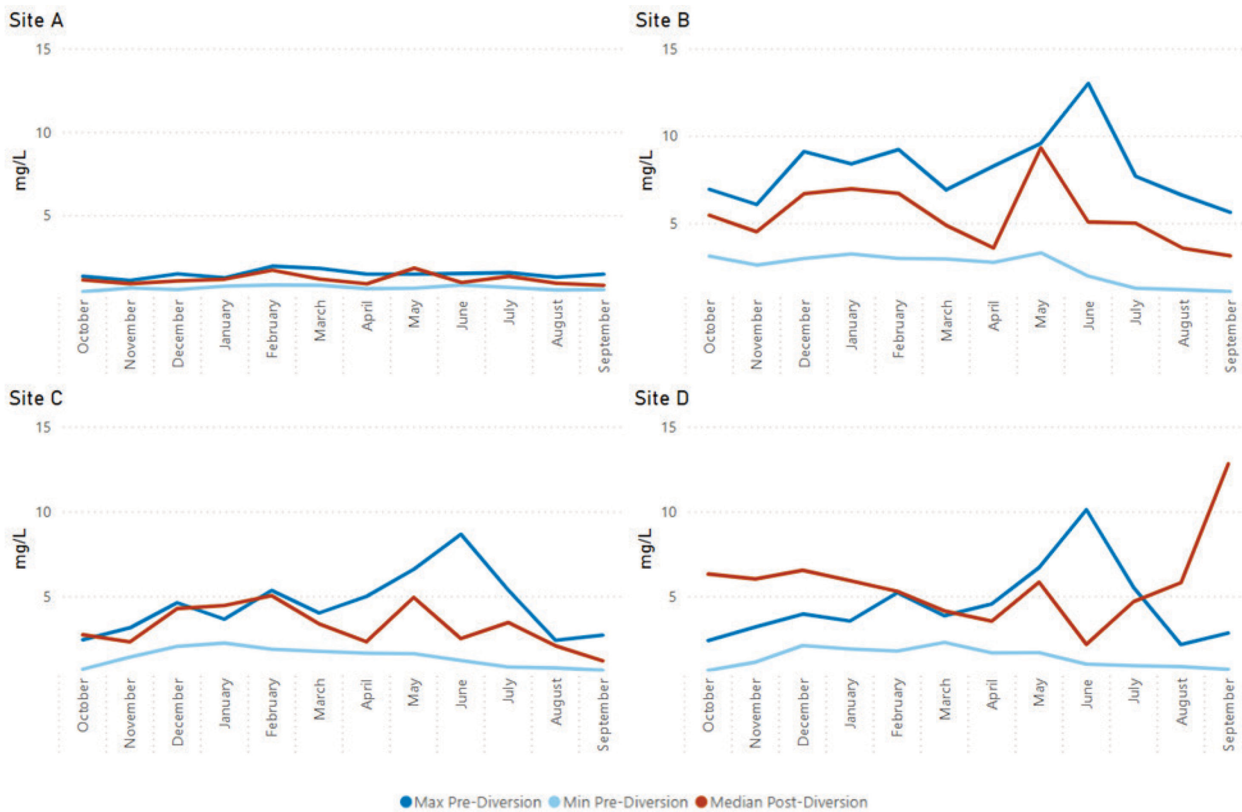
Orthophosphate Observations

- Increased orthophosphate concentrations in the reporting period above the maximum pre-diversion concentrations occurred in the months of February, April, and May at Sites B, C, and D. The results indicate that Site B significantly impacts downstream orthophosphate concentration at Sites C and D.
- During the reporting period, orthophosphate concentrations decreased on average from 0.06 mg/L at Site C to 0.05 mg/L at Site D.

6.2.8.4 Total Nitrogen

Figure 6-16 compares the maximum and minimum total nitrogen results during the pre-diversion period with the median total nitrogen results from the reporting period.

Figure 6-16. Maximum and Minimum Total Nitrogen During the Pre-Diversion Period Compared to Median Total Nitrogen Concentrations in the Root River for the First Year of the Reporting Period



Note: For the months of January to May and November to December, the median reporting period data are based on a single sampling data point. For the months of June to October, data are based on two sampling data points.

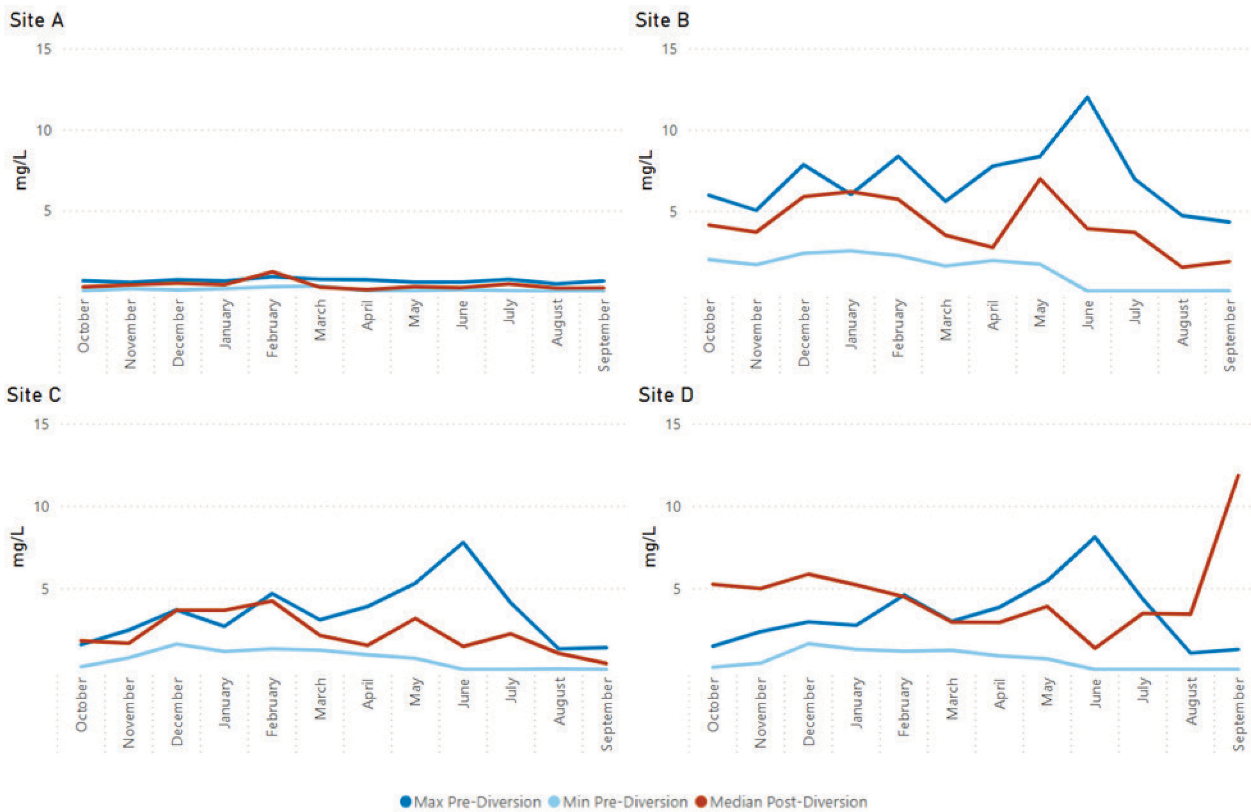
Total Nitrogen Observations

- Nitrogen trends at Site B are consistent with those observed at Sites C and D, except for August and September. The observed peaks may in part be from low flow conditions in the Root River. In August and September, return flow constituted 21.7% and 54.4% of the total flow in the Root River, respectively, at Site D. Despite these low-flow conditions, all total nitrogen measurements remained below the QAPP expected range concentration (Table 6-1), indicating that the concentrations were still within expected environmental ranges.

6.2.8.5 Nitrate-Nitrite

Figure 6-17 compares the maximum and minimum nitrate-nitrite results during the pre-diversion period with the median nitrate-nitrite results from the reporting period.

Figure 6-17. Maximum and Minimum Nitrate-Nitrite During the Pre-Diversion Period Compared to Median Nitrate-Nitrite Concentrations in the Root River for the First Year of the Reporting Period



Note: For the months of January to May and November to December, the median reporting period data are based on a single sampling data point. For the months of June to October, data are based on two sampling data points.

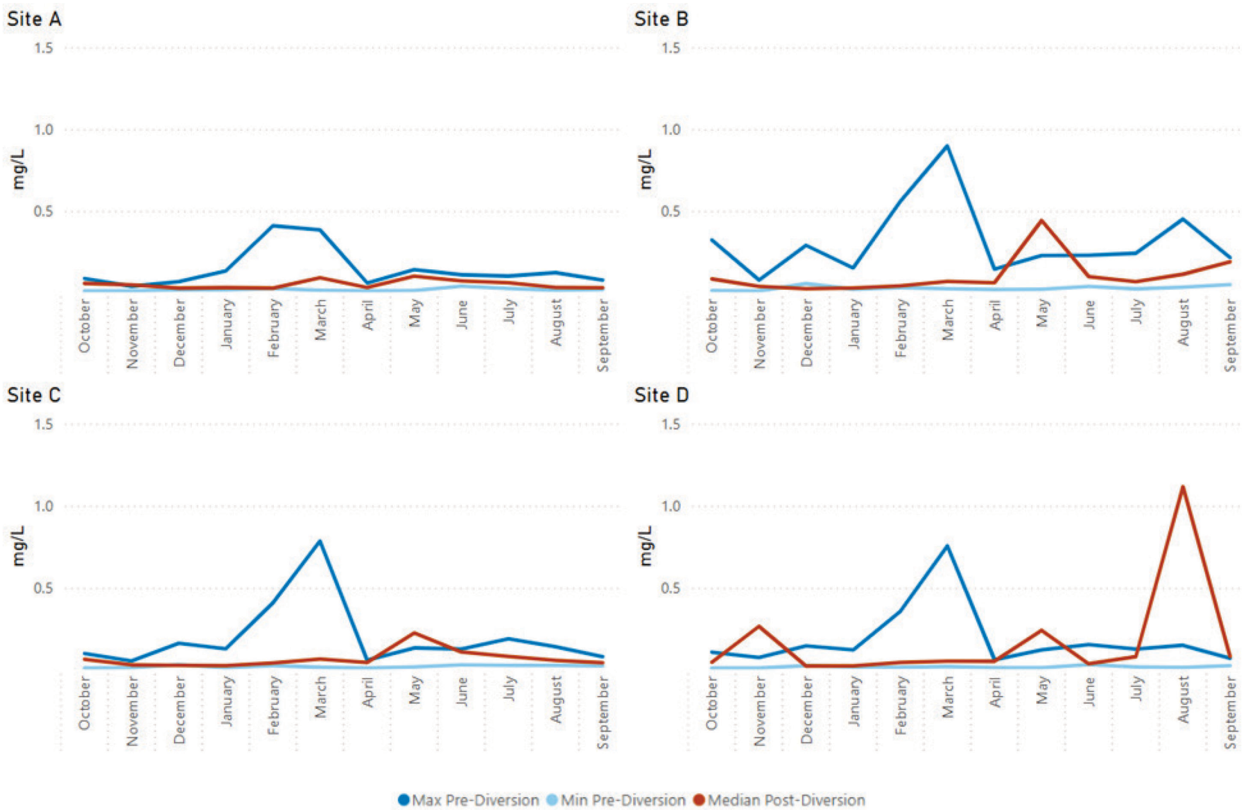
Nitrate-Nitrite Observations

- Nitrate-nitrite levels exhibited trends similar to those of total nitrogen during the reporting period.
- From December through July, nitrate-nitrite levels at Site D were influenced by upstream concentrations.
- In August, September, October, and November, nitrate-nitrite levels at Site D were greater than upstream concentrations and pre-diversion maximums.
- The observed peaks are may in part be due to low flow conditions in the Root River. In August and September, return flow constituted 21.7% and 54.4% of the total flow in the Root River, respectively. Despite these low-flow conditions, all nitrate-nitrite measurements remained below the QAPP expected range concentration (Table 6-1), indicating that the concentrations were still within expected environmental ranges.

6.2.8.6 Ammonia

Figure 6-18 compares the maximum and minimum ammonia results during the pre-diversion period with the median ammonia results from the reporting period.

Figure 6-18. Maximum and Minimum Ammonia During the Pre-Diversion Period Compared to Median Ammonia Concentrations in the Root River for the First Year of the Reporting Period



Note: For the months of January to May and November to December, the median reporting period data are based on a single sampling data point. For the months of June to October, data are based on two sampling data points.

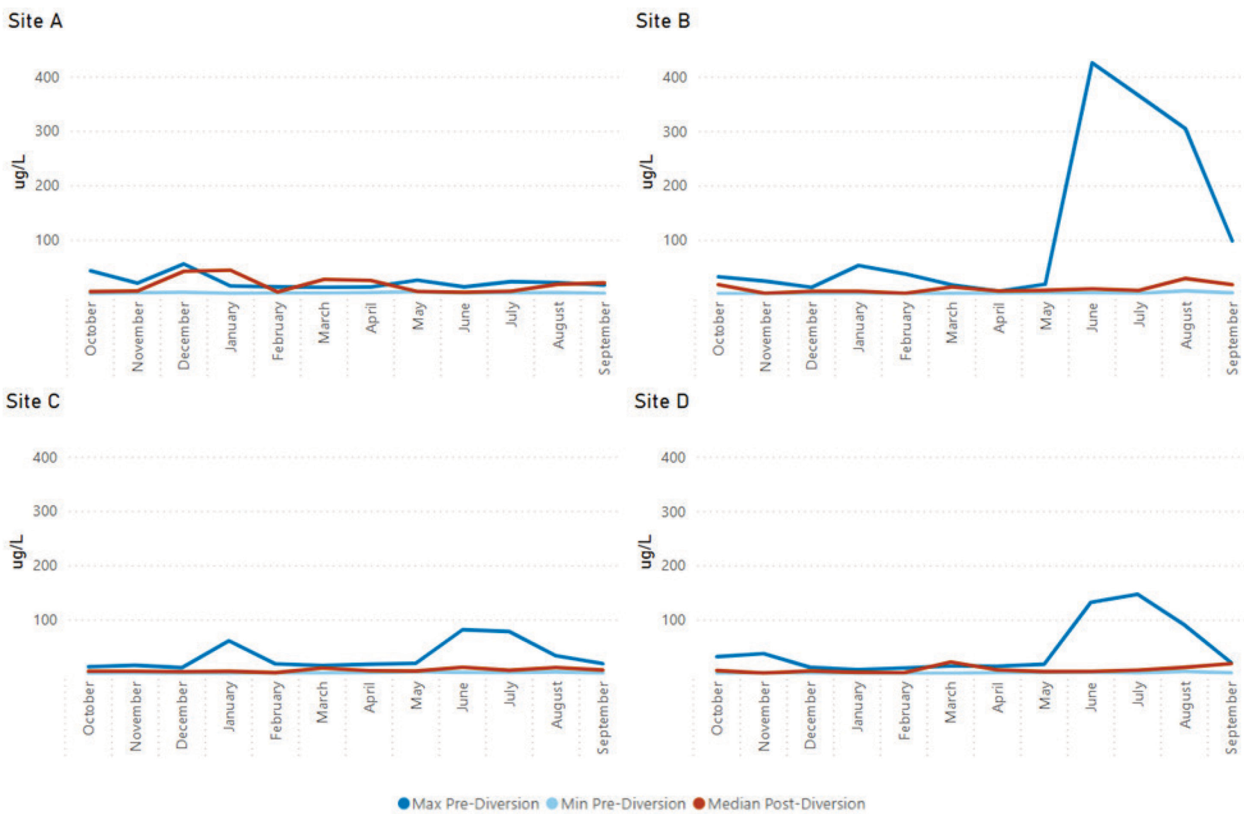
Ammonia Observations

- In all months of the reporting period, apart from August, ammonia levels at Site D were influenced by upstream concentrations.
- In August of the reporting period, ammonia levels at Site D exceeded both upstream concentrations and pre-diversion maximums.
- The observed peaks may, in part, be from low-flow conditions in the Root River. In August, return flow constituted 21.7% of the total flow in the Root River. Despite these low-flow conditions, all ammonia measurements remained below the QAPP expected range concentration (Table 6-1), indicating that the concentrations were still within expected environmental ranges.
- During November and August, there were three days when return flow had ammonia concentrations above nondetectable levels but still within permitted limits. Coincidentally, those days overlapped the single monitoring event in these months, resulting in a Site D graphic that captures these unique conditions instead of more typical river conditions when nearly all days had nondetectable levels of ammonia in return flow.

6.2.8.7 Chlorophyll

Figure 6-19 compares the maximum and minimum chlorophyll results during the pre-diversion period with the median chlorophyll results from the reporting period.

Figure 6-19. Maximum and Minimum Chlorophyll Concentrations During the Pre-Diversion Period Compared to Median Chlorophyll Concentrations in the Root River for the First Year of the Reporting Period



Note: For the months of January to May and November to December, the median reporting period data are based on a single sampling data point. For the months of June to October, data are based on two sampling data points.

Chlorophyll Observations

- During the reporting period, chlorophyll concentrations increased on average from 4.83 µg/L at Site C to 5.85 µg/L at Site D, which is consistent with the pre-diversion period in which chlorophyll concentrations increased on average from 8.91 µg/L at Site C to 12.51 µg/L at Site D.
- Chlorophyll concentrations at Site D remained within the historical range observed in the pre-diversion period, with the exception of a slight deviation in March.
- Chlorophyll concentrations at Site A in the reporting period exceeded the pre-diversion range maximum in the months of January, March, April, and September.
- Chlorophyll concentrations at Sites B and C remained within the historical range observed in the pre-diversion period.

6.2.9 Watershed Impacts

Watershed impacts from environmental events as well as human activity during the reporting period were reviewed to assess potential observational impacts in recorded water quality data. The following activities were completed to summarize watershed impacts during the post-return flow data collection period:

- Contacted Milwaukee RiverKeeper for records of environmental releases and similar impacts.
- Performed Internet searches for local news stories.
- Queried the *Milwaukee Journal Sentinel* online articles.
- Obtained records from the WDNR Spills Coordinator.
- Had verbal conversations with local farmers.

Upstream of the return flow outfall on the Root River Canal, upstream of Site B, there are two active wastewater discharges governed by Wisconsin Pollutant Discharge Elimination System permits.
Both facilities operate under the Multi-Discharger Variance for phosphorus and are, therefore, permitted to have phosphorus discharges above the water quality criterion. Water quality data collected during the pre-diversion period demonstrated higher phosphorus levels at Site B consistent with the presence of these discharges.

To assess acute impacts to the Root River during the reporting period, spill activities were reviewed using the WDNR Environmental Cleanup and Brownfields Redevelopment database. During the reporting period, a total of three spills were recorded along the Root River, with two spills located downstream of the sampling sites and one spill located upstream of all the sampling sites. Spill activity in the Root River area from October 2023 through September 2024 with potential impacts to sampling sites are shown in Table 6-17.

Table 6-17. Spill Incidents along Root River Sampling Sites in the Pre-Diversion Period

Start and End Date	Spill Substance	Amount Released	Location	Potential Sampling Site(s) Impacted	Description
09-01-2023 to 01-17-2024	Petroleum	Unknown	State Trunk Highway (STH) 31 and Johnson Ave	Downstream	Leak of potentially large amount of oil or hydraulic fluid from abandoned car
12-14-2023 to 12-20-2023	Wastewater	Unknown	S 68th St and W Rawson Ave	Sites A, C, C2, and D	Discharge of milky white, cloudy water from quarry
05-06-2024 to 05-08-2024	Gasoline	15 gallons	Main St bridge and Root River	Downstream	Leak from gasoline container in capsized boat in the Root River

To assess the impacts of gasoline, wastewater, and petroleum spills, reviews of turbidity and pH data were conducted. For the petroleum and gasoline spill date ranges, no substantial deviations in data results were observed which was consistent with the spills located downstream of the sampling sites. Following the wastewater spill (upstream of all sampling sites), higher turbidity levels were noted during the January 2, 2024, sampling event in comparison to the November 11 and December 13, 2023, sampling events. Specifically, the average turbidity across all sites increased from 5.31 NTUs to 10.55 NTUs. Additionally, minor variations in pH values (ranging between 7.75 and 8.04) were observed at Sites A, B, C, and D from

December 2023 through January 2024. Despite these variations, all turbidity and pH values remained within the expected data ranges outlined in the QAPP.

7 Water-Dependent Resources

Fish, benthic macroinvertebrate, and quantitative habitat evaluation surveys were completed at Sites A through D starting in 2017. This report augments the Pre-Diversion Root River Data Collection Summary (Jacobs 2024) by incorporating the pre-diversion data from the July 2023 habitat evaluation and September 1, 2023, macroinvertebrate sampling (Orlofske 2024). This report also incorporates the reporting period events from the November 2023 macroinvertebrate survey, and November 2023 and preliminary draft July 2024 fish surveys (Schulz 2024). While the November 2023 fish and macroinvertebrate surveys occurred during reporting period conditions, they were conducted shortly after the final transition to Lake Michigan was complete.

Table 7-1 summarizes the pre-diversion period and reporting period sampling dates between 2017 and 2024. The September 1, 2023, sampling event was during the pre-diversion period; however, there was some intermittent return flow on days leading up to this event as the City was preparing and testing equipment for the transition.

Table 7-1. Summary of Macroinvertebrate and Habitat Survey Events

Year	Benthic Macroinvertebrate Sampling		Quantitative Habitat Evaluation			
	September	November	Site A	Site B	Site C	Site D
2017	Sept. 11	Nov. 2	Sept. 21	Sept. 19	Sept. 24	Sept. 19
2018	Sept. 13	Nov. 17	Sept. 27	Sept. 20	Sept. 14	Sept. 14
2019	Sept. 5	Nov. 13	Sept. 6	Sept. 20	Sept. 26	Nov. 14
2020	Sept. 3	Nov. 4	Sept. 18	Sept. 11	Sept. 24	Sept. 17
2021	Sept. 3	Nov. 3	Aug. 5	July 27	July 29	Aug. 6
2022	Sept. 2	Nov. 2	July 13	July 8	July 14	July 18
2023	Sept. 1	Nov. 11[a]	July 7	July 3	July 18	July 17
2024	Sept. 3[a,b]	Nov. 2[a,b]	July 19[a]	July 1[a]	July 11[a]	July 12[a]

Notes:
[a] = reporting period flow conditions
[b] = results not available to be included in this report

Table 7-2 summarizes the sampling dates for the pre-diversion period and reporting period fish surveys conducted between 2017 and 2024. All sites were sampled as part of the same survey, except in 2017, when a second event for Sites C and D was required to ensure the sampling was conducted over the defined study reach.

Table 7-2. Summary of Fish Survey Events

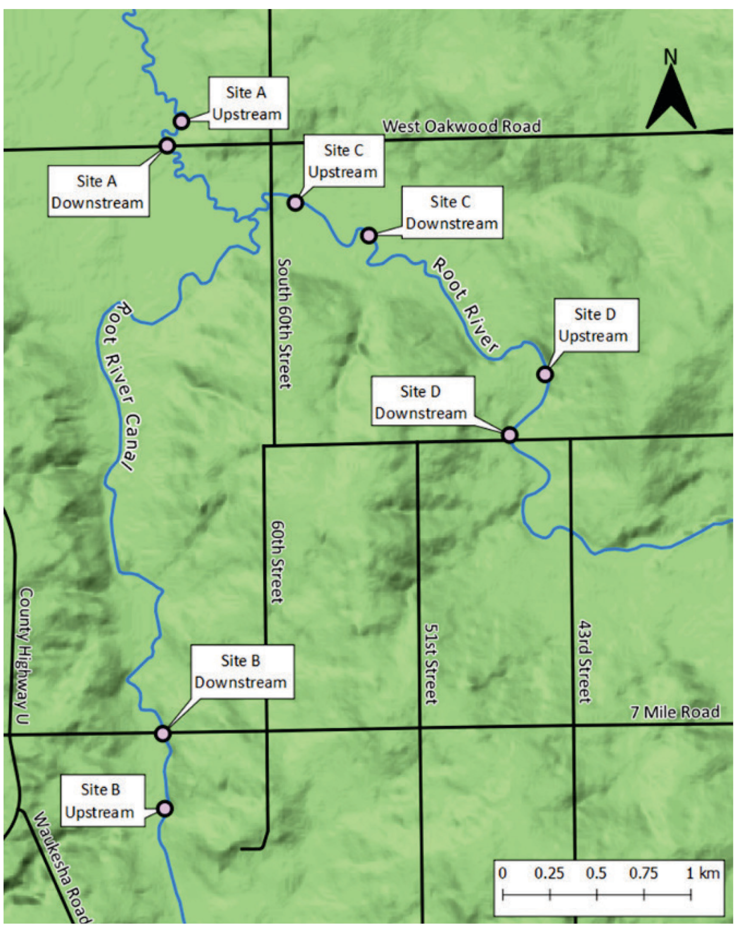
Year	Fish Surveys	
	Summer	Fall
2017	July 27 & 28, Sept. 1	Nov. 7 & 8
2018	July 9 & 10	Nov. 13 & 14

Year	Fish Surveys	
	Summer	Fall
2019	July 26 & 27	Nov. 8 & 9
2020	Aug. 7 & 8	Nov. 5 & 7
2021	July 20 & 22	Nov. 4 & 6
2022	July 22 & 23	Nov. 10 & 11
2023	July 20 & 21	Nov. 6 & 7[a]
2024	July 22 & July 23[a]	Nov. 16 & 17[a,b]

Notes:
[a] = reporting period flow conditions
[b] = results not available to be included in this report

The sampling reaches were established in 2017 and repeated through 2024 (Figure 7-1). Reach lengths differed for each location in proportion to the stream width. Although water levels and, therefore, stream widths differed in 2022 compared to 2017, 2018, 2019, 2020, and 2021, the transects established in 2017 were resampled in 2022 for consistent comparisons. The return flow outfall is near the upstream end of Site C reach.

Figure 7-1. Survey Reaches



7.1 Fish Community

Fish sampling was conducted in accordance with the Standard Operating Procedure for the Collection, Identification, and Enumeration of Fishes for the Pre-Return Flow Root River Data Collection Plan (CH2M 2017) and the QAPP (Jacobs 2023) for reporting period conditions. Captured fish were identified in the field, counted, and released; four statistics were calculated at each sampling location from 2017 through 2024: Catch Per Unit Effort (CPUE), Shannon Diversity Index, Index of Biotic Integrity for Warm Water Fish Communities (Warm F-IBI), and Index of Biotic Integrity for Cool-Warm Water Fish Communities (Cool-Warm F-IBI). Data from these four statistical analyses are displayed as summer (July, August, and September sampling dates) and fall (November sampling dates) for comparison of seasonal differences. No threatened, endangered, or special-concern species were encountered at any of these locations. None of the fish collected presented deformity, erosion, lesion, or tumor.

7.1.1 Catch Per Unit Effort

CPUE is the number of fish caught per hour of sampling. CPUE provides information on the overall density of fish in the river. Fish exhibit spatial and temporal variations in their distribution and activity; therefore, CPUE may vary widely. The CPUE during the summer and fall surveys is shown on Figures 7-2 and 7-3. The November 2023 and preliminary draft July 2024 data are included in this report as part of the reporting period flow environment. Note that data for November 2024 fish sampling dates were unavailable at the time this report was created and, therefore, will be incorporated in the next annual report.

Figure 7-2. Summer Fish Survey Catch Per Unit Effort

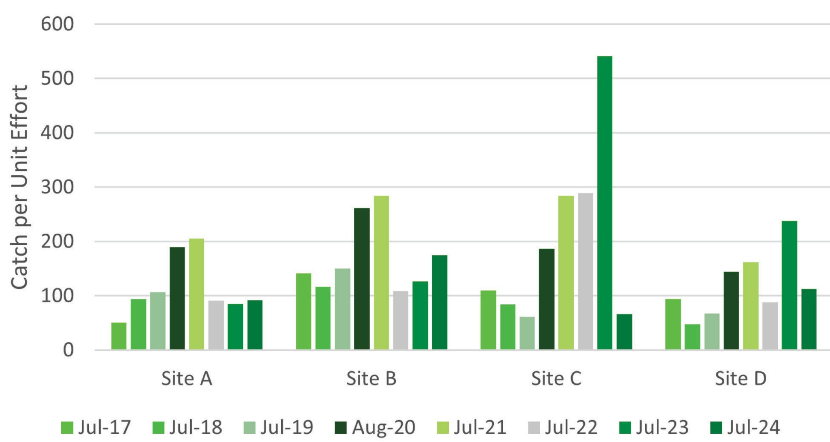
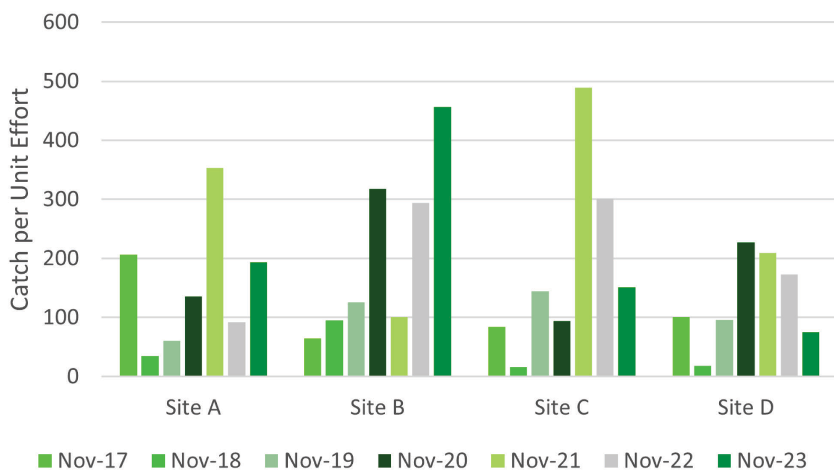


Figure 7-3. Fall Fish Survey Catch Per Unit Effort



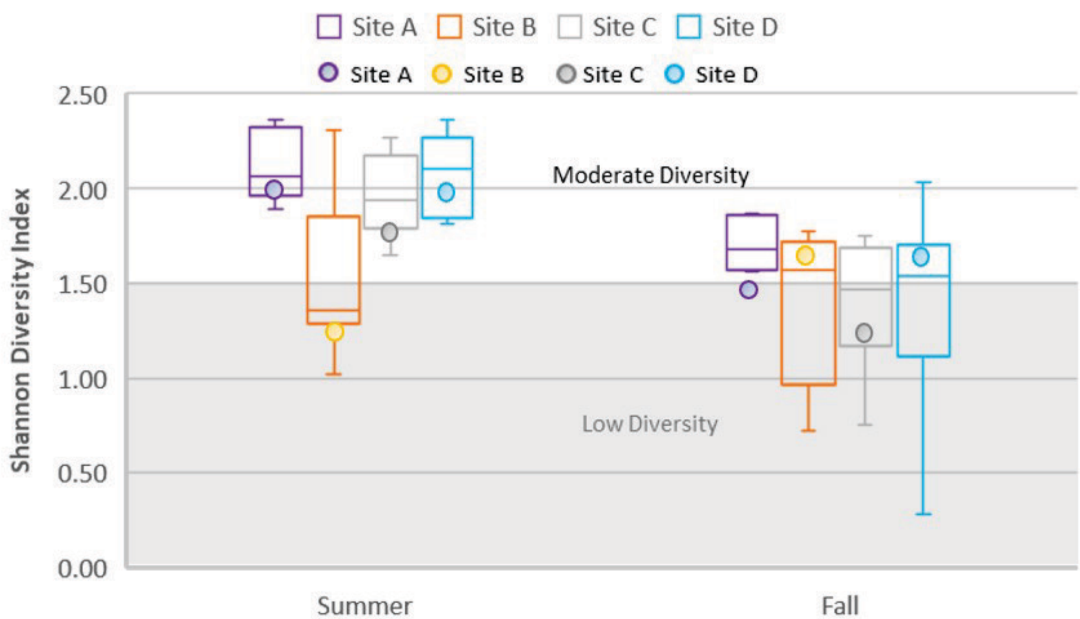
7.1.1.1 CPUE Observations

- The total number of individuals captured at each location during the summer and fall sampling events continues to be variable.
- Reporting period CPUE values are within the range of pre-diversion values, except for upstream Site B in November 2023 that saw the greatest CPUE over all sampling events.

7.1.2 Shannon Diversity Index

Shannon Diversity Index allows comparison of both the richness (number of species present) and evenness (number of individuals per species) of species in a community. This provides a measure of diversity that can be used to compare communities, habitats, or locations regarding how many individuals of how many species are present. The Shannon Diversity Index typically ranges from 0 to 3.5, where values from 0 to 1.5 would indicate low diversity, values from 1.51 to 2.5 indicate moderate diversity, and values above 2.51 indicate high diversity. Figure 7-4 shows Shannon Diversity Index values across summer (July, August, and September) and fall (November) sampling events for both pre-diversion (box and whisker plot) and reporting period (shaded circle) events.

Figure 7-4. Shannon Diversity Index: Pre-Diversion Period (Box and Whisker Plot) and Reporting Period (Single Sample Points)



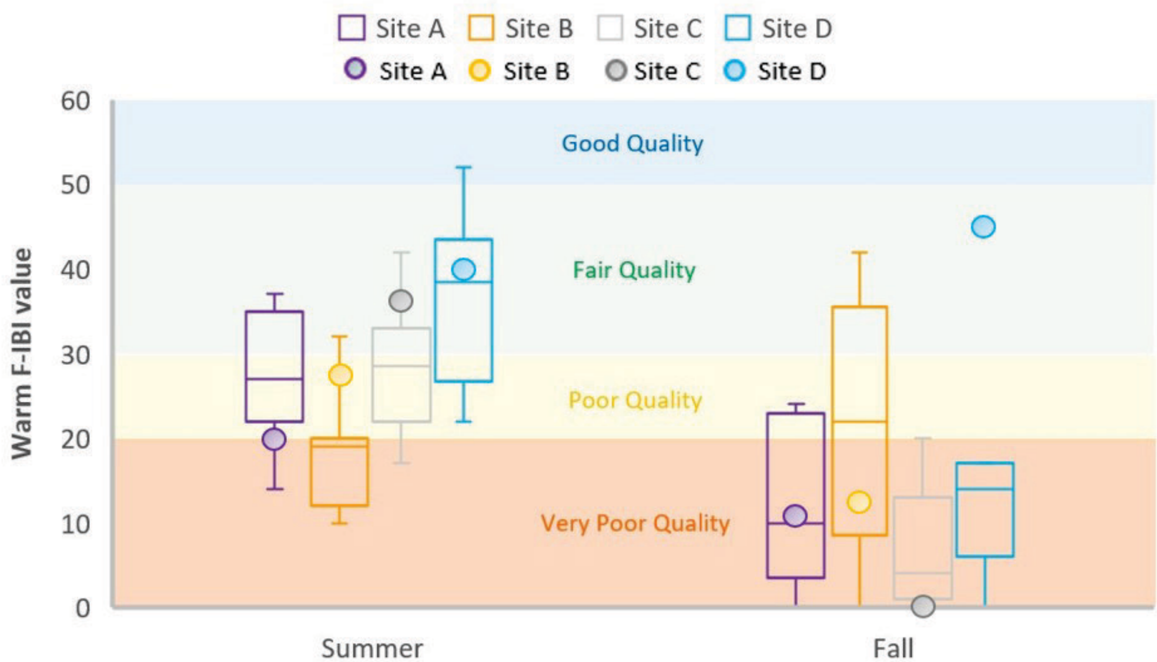
7.1.2.1 Shannon Diversity Index Observations

- The Shannon Diversity Index values for the four locations across 7 years of summer sampling consistently indicated low to moderate levels of species diversity. Shannon Diversity Index values were most variable at Site B across summer sampling events.
- The Shannon Diversity Index values for the four locations across 6 years of fall sampling have ranged between low and moderate levels of species diversity. Site A has the most consistent scores across all six sampling events, with moderate Shannon Diversity Index values. Sites B, C, and D varied between low and moderate Shannon Diversity Index values during the fall sampling events.
- The single reporting period event for both summer and fall was within the range of pre-diversion events with the exception that the fall reporting period event at upstream Site A was slightly less.

7.1.3 Index of Biotic Integrity (IBI) for Warm Water Fish Communities

The IBI is a set of calculations based on the ecological characteristics of the fish present in each community. The warm water IBI (Warm F-IBI) calculation accounts for the number of each species caught; the number of tolerant, hardy species versus the number of intolerant, sensitive species; the number of native versus the number of introduced species; the ecological niches (carnivore, omnivore, herbivore) of the species in the sample; the presence of species that require clean, sediment-free gravel and pebbles to spawn; and the presence of certain species (darters, sunfish, suckers, and salmonids) in the sample. The resulting calculation is a single value indicating the overall quality of the stream habitat, indicating the likelihood of environmental degradation or pollution. The Warm F-IBI score ranges from 0 to 100, with scores of 0 to 19 rated as very poor quality, 20 to 29 rated as poor quality, 30 to 49 rated as fair quality, 50 to 64 rated as good quality, and 65 to 100 rated as excellent quality. Figure 7-5 shows Warm F-IBI values across summer (July, August, and September) and fall (November) sampling events. Note that November 2018 was below the minimum required number of individuals to calculate an IBI score.

Figure 7-5. Index of Biotic Integrity for Warm Water Fish Communities: Pre-Diversion Period (Box and Whisker Plot) and Reporting Period (Single Sample Points)



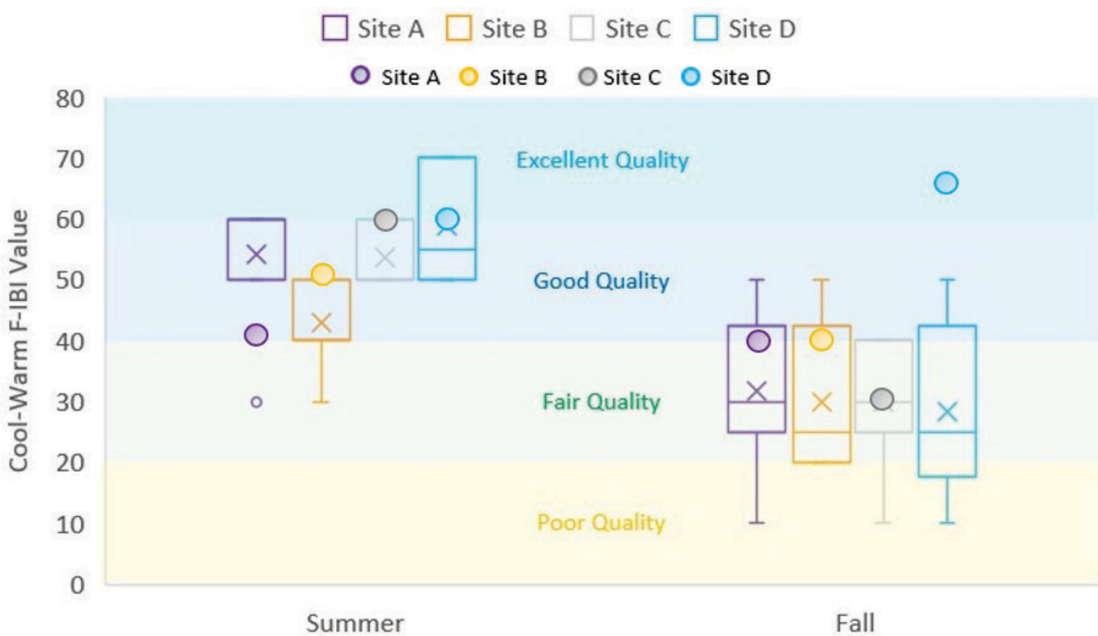
7.1.3.1 Warm Water Fish IBI Observations

- All reporting period locations had warm F-IBI scores within the range observed during the pre-diversion conditions, except for Site D in November 2023, which had the highest value during fall events.
- In November 2023, Site C received a Warm F-IBI value of 0.
- In November 2023, Site D received its highest warm F-IBI value of 45, which may be attributed to the large number of insectivores and low number of tolerant species caught at this location.
- July 2024 values are consistent with pre-diversion flow data ranges.
- As reported in the pre-diversion data summary report (Jacobs 2024), the Warm F-IBI values in summer surveys typically ranged from very poor to fair quality. Only one location during one sampling event resulted in a good rating (Site D, September 2017).
- As reported in the pre-diversion data summary report (Jacobs 2024), the Warm F-IBI values in all November surveys typically ranged from very poor to poor quality, reflecting that in-stream habitats become inhospitable to most fish during the fall, largely because of the cold temperatures these shallow regions of the Root River experience beginning in October and lasting into mid spring.
- As reported in in the pre-diversion data summary (Jacobs 2024), Site B had an IBI ranking of fair because of the unexpected number and diversity of fish captured, attributed to very warm weather in early November of 2020.

7.1.4 Index of Biotic Integrity for Cool-Warm Water Fish Communities

The cool-warm water IBI (Cool-Warm F-IBI) calculation accounts for the number of native minnow species; the number of intolerant species; the percentage of tolerant species; the number of benthic invertivore species; and the percentage of omnivores. The resulting calculation is a single value indicating the overall quality of the stream habitat, indicating the likelihood of environmental degradation or pollution. The Cool-Warm F-IBI score ranges from 0 to 100, with scores of 0 to 20 rated as poor quality, 21 to 40 rated as fair quality, 41 to 60 as good quality, and 61 to 100 rated as excellent quality. Figure 7-6 shows Cool-Warm F-IBI values across summer (July, August, and September) and fall (November) sampling events.

Figure 7-6. Index of Biotic Integrity for Cool-Warm Water Fish Communities: Pre-Diversion Period (Box and Whisker Plot) and Reporting Period (Single Sample Points)



7.1.4.1 Cool-Warm Fish IBI Observations

- November 2023 Cool-Warm F-IBI values are consistent with pre-diversion ranges, with an increase to Excellent Quality at Site D for the single reporting period sampling event.
- July 2024 Cool-Warm F-IBI values are consistent with pre-diversion flow data ranges.

7.2 Macroinvertebrates

7.2.1 Hilsenhoff Biotic Index

The Hilsenhoff Biotic Index (HBI) value (index ranges from 0 to 10, with lower values indicating higher quality and higher values indicating lower quality) is used to indicate overall water quality – specifically, the presence of organic pollution that would deprive organisms, such as aquatic macroinvertebrates, of dissolved oxygen necessary for cellular respiration. Samples containing more individuals with greater tolerance scores result in greater HBI values, indicating lower water quality and a greater probability of organic pollution. Conversely, samples containing more individuals with lower tolerance scores result in lower HBI values, indicating higher water quality and a smaller probability of organic pollution (Hilsenhoff 1988). Table 7-3 summarizes the range of HBI values correlating to a water quality rating and degree of organic pollution.

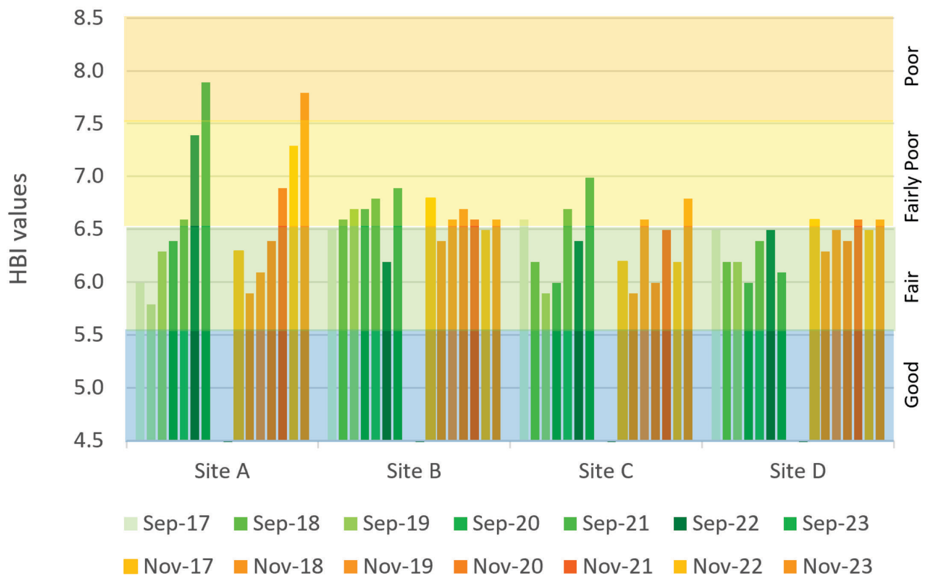
Table 7-3. Hilsenhoff Biotic Index Ranges

HBI Value	Water Quality Rating	Degree of Organic Pollution
<3.50	Excellent	None apparent
3.51 to 4.50	Very Good	Possible slight
4.51 to 5.50	Good	Some
5.51 to 6.50	Fair	Fairly significant
6.51 to 7.50	Fairly Poor	Significant
7.51 to 8.50	Poor	Very significant
8.51 to 10.00	Very Poor	Severe

Macroinvertebrate surveys were conducted during two time periods (early fall and late fall) for eight sequential years, with seven years available for comparison for this report. Persistent low flows in 2020, 2021, and 2022 may have exacerbated stressful conditions for sensitive taxa at the four locations and may have contributed to lower abundance values in each of these sampling years. Figure 7-7 summarizes the range of HBI values for each sampling site over the past 7 years. Note that benthic macroinvertebrates were sampled on September 1, 2023, and November 11, 2023, with the November sampling event occurring shortly after the final transition to Lake Michigan water was completed. The timing of invertebrate sampling in 2023 was comparable to sampling that occurred during the preceding 6 years.

Overall, macroinvertebrate metric and index values have remained relatively consistent across most years and seasons despite minor fluctuations in taxonomic composition of the benthic macroinvertebrates. As with composition, metric and index scores seem to follow large-scale conditions, such as water level. Surveys during low-flow periods (2018, 2021, 2022, and 2023) are more similar. Likewise, surveys during high-flow periods (2019 and 2020) are more similar. However, fluctuations among years are still relatively minor.

Figure 7-7. Hilsenhoff Biotic Index – Bar Graph by Site and Sampling Date



7.2.1.1 HBI Observations for Reporting Period Conditions

- HBI values at Site A during September 2023 and November 2023 indicated poor water quality and very significant degree of organic pollution for the first time in 7 years of sampling.
- The HBI scores are consistent with patterns observed in the MPTV scores for each of these Root River and Root River Canal sampling locations.

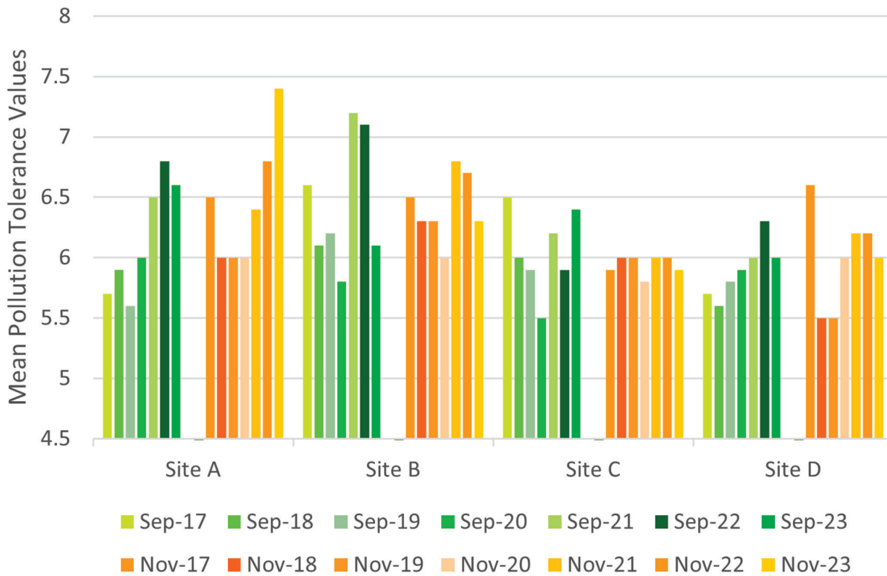
7.2.2 Macroinvertebrate Index of Biological Integrity

As requested by WDNR, the macroinvertebrate index of biological integrity (M-IBI) was calculated for pre-diversion period and reporting period data sets (Orlofske 2025). The following metrics are included in the M-IBI for wadeable streams: species richness, Ephemeroptera-Plecoptera-Trichoptera, Mean Pollution Tolerance Value, proportion of depositional taxa, proportion of Diptera, proportion of Chironomidae, proportion of shredders, proportion of scrapers, proportion of gatherers, proportion of Isopoda, and proportion of Amphipoda. Overall, the M-IBI scores and ratings are consistent with the evaluation of the component metrics and index values described in detail in the annual benthic macroinvertebrate and habitat monitoring reports (Orlofske 2018 through 2024). A summary of M-IBI values is included in Attachment A.

7.2.3 Mean Pollution Tolerance Value

The mean pollution tolerance value (MPTV) represents the average pollution tolerance value for the macroinvertebrates collected in a sample. Low tolerance values are assigned to taxa that are considered sensitive to organic pollution while higher tolerance values are assigned to taxa that are considered tolerant to organic pollution. This metric calculates the average tolerance score for the taxa present in the sample and is complementary to the HBI because both measures use the same tolerance values. However, the MPTV is not influenced by macroinvertebrate abundance. The MPTV has a range from 0 to 10, with lower values indicating lower average pollution tolerance values (fewer high tolerance value taxa or more low tolerance value taxa) and higher values indicating higher average pollution tolerance values (fewer low tolerance value taxa or more high tolerance value taxa). Figure 7-8 summarizes the range of MPTV for each sampling site over the past 7 years.

Figure 7-8. Mean Pollution Tolerance Value by Site and Sampling Date



7.2.3.1 MPTV Observations for Reporting Period Conditions

- The November 2023 sampling event occurred shortly after the diversion was completed, however Site A had an increase in MPTV value, indicating more high tolerance value taxa, whereas all other sites the MPTV decreased from the prior year or was within the range and near the average from all previous November sampling events.
- The same as past observations, pollution-tolerant taxa continue to be more common than pollution-sensitive taxa at all four locations for each sampling period.

7.2.4 Additional Reporting Period Observations

Aquatic macroinvertebrate counts were similar among locations and between seasons in 2023. The 2023 benthic macroinvertebrate surveys were first to produce a winter stonefly (Plecoptera, Taeniopterygidae, *Taeniopteryx*), which is a highly pollution-sensitive species. Another taxon recovered for the first time in 2023 was *Erioptera*, a relatively pollution-tolerant cranefly. All other benthic macroinvertebrate taxa observed in 2023 have been present in at least one sample during the previous 6 years of surveys. The Amphipod, *Hyalella*, which first appeared among the three most abundant taxa in 2021 and recorded among the three most abundant taxa in 2022, was the most abundant macroinvertebrate taxon observed during the 2023 surveys. *Hyalella* seems to benefit from the expanding area of submerged macrophytes, particularly at Site A. *Hyalella* is classified as pollution tolerant and contributed to the relatively high organic pollution metric and index values for the 2023 surveys, especially for Site A. The increase in *Hyalella* over the years can increase the MPTV and HBI values.

7.3 Habitat

A wadeable stream quantitative habitat evaluation was conducted at each site and over the entire sampling period. Prior to 2021, habitat assessment surveys were conducted in September alongside the aquatic macroinvertebrate sampling. However, the timing of the habitat evaluation changed in 2021 to assess conditions present during summer fish surveys. This change was made to better align with staffing availability and the habitat assessment protocols. No significant changes were observed by the field teams by switching the assessment period to a month earlier in the year.

The same physical and chemical parameters – specifically, pH (S.U.), dissolved oxygen (mg/L), conductivity (mS/cm), water temperature (°C), and turbidity (NTU) – measured during the macroinvertebrate surveys also were assessed during the habitat surveys. Water temperatures were generally warm (22.1°C ± 1.1°C) during the habitat surveys, consistent with their classification as warm water streams. Variation in precipitation events and the associated effects on flow among survey dates may contribute to the minor variations observed in these parameters among sites and sampling dates. The persistence of log jams and coarse woody debris in the channels observed during summer habitat assessment surveys and both benthic macroinvertebrate collection periods suggest that sediment sorting and redistribution at each of these Root River and Root River Canal locations may only occur during peak flows (the spring freshet). Low to moderate flows in 2023 permitted the measurement of hydrologic conditions yet did not impede the evaluation of substrate characteristics to the same degree experienced in 2022.

Substrate, adult gamefish cover, bank erosion data, and algal abundance from the 2023 habitat surveys are summarized in the following subsections. The data from 2024 habitat monitoring were unavailable at the time of this report and will be incorporated in the next annual report. Consequently, the habitat survey discussions below are for pre-diversion conditions only and augment the summaries provided in the 2023 annual report (Jacobs 2024).

7.3.1 Substrate Data

Overall, the four sites are dominated by fine sediment, including a relatively high percentage of silt, clay, and sand with smaller contributions of larger bed material and moderate amounts of organic material, including the submerged and emergent macrophytes. Organic material continues to be a dynamic component of the substrate at most locations. Water levels in November 2023 were higher than during the September 2023 surveys, but most conditions, including substrate, were largely similar between survey periods. The sites' primary composition is unchanged:

- Site A consisted primarily of silt (ranging from 65.53% to 94.66%) and clay (0 to 20.91%).
- Site B consisted primarily of gravel (6.17% to 29.53%), sand (4.20% to 31.91%), and silt (38.27% to 77.25%).
- Site C consisted primarily of sand (0.90% to 26.66%), silt (51.41% to 93.56%), and organic/detritus (2.14% to 21.00%).
- Site D consisted primarily of gravel (12.10% to 31.92%), sand (0 to 21.01%), silt (26.96% to 83.89%), and organic/detritus (0.14% to 20.73%).

7.3.2 Cover for Adult Gamefish

Evidence of fish habitat was documented as part of the surveys. Fish habitat was documented at all sites; however, the type of habitat and the extent of the habitat (number of transects) differed at each location.

The proportion and distribution of gamefish habitat differs slightly among years, but several types of fish habitat generally are available in each study reach each year. Despite variation among flow conditions and survey timing, woody debris continues to be the dominant fish cover among all sites, while submerged macrophyte beds persist, particularly at Site A, and overhanging banks appear in a few places. Woody debris and submerged macrophytes occurred at all locations in 2023 and the extent of submerged macrophyte coverage was nearly the same as the extent of woody debris.

7.3.3 Bank Erosion

During the quantitative habitat evaluation, the degree of bank erosion was assessed by measuring the height of exposed soil within 1 meter of the wetted edge on the left and right banks (facing upstream) at each transect. The evaluation of the extent of exposed bank is influenced by water depth and discharge in the channel at the time of the survey. Thus, these instantaneous, empirical values should still be considered estimates of site characteristics. The average bank erosion measurement for 2023, collected during a low to moderate flow period was 1.7 meters (± 1.0 meter). This value was slightly lower than the value recorded in 2022 (2.1 meters ± 1.1 meters) at slightly higher flows and slightly higher than the value recorded in 2021 (1.2 meters ± 0.7 meter) at slightly lower flows. Thus, the 2023 estimate of bank erosion is intermediate to the previous bank erosion estimates collected during summer habitat assessment surveys. Table 7-4 presents exposed bank heights from 2017 to 2023.

7.3.4 Algal Abundance

Algal abundance sampling began during the 2021 habitat assessment using an algal viewing bucket. The percentage of algae present was documented at each transect to the nearest 10% at each channel position representing one-fifth of the stream width. Algae generally were observed infrequently. In 2021, Site A had the greatest occurrence of algae across transects and channel positions ranging from 0 to 70%. In 2022, algae were observed at one channel position in one transect at Site A. In 2023, four transects at Site A and three transects at Site B had visible attached or filamentous algae present in at least one position. Overall, the presence of attached and filamentous algae is low at all Root River and Root River Canal locations. This is consistent with the low percentage of benthic macroinvertebrates categorized as scrapers in each of the benthic macroinvertebrate monitoring samples.

Table 7-4. Exposed Bank Heights Through 2023 (Pre-Diversion Conditions)

Year	Site A			Site B			Site C			Site D		
	Left	Right	Avg	Left	Right	Avg	Left	Right	Avg	Left	Right	Avg
2017	1.0 ± 0.5 m	1.0 ± 0.6 m	**1.0 m**	1.0 ± 1.1 m	1.5 ± 0.7 m	**1.3 m**	2.9 ± 1.9 m	3.2 ± 2.0 m	**3.1 m**	3.3 ± 2.5 m	2.3 ± 1.4 m	**2.8 m**
2018	0.3 ± 0.4 m	0.5 ± 0.3 m	**0.4 m**	0.6 ± 0.6 m	0.5 ± 0.6 m	**0.5 m**	1.3 ± 0.7 m	0.9 ± 0.6 m	**1.1 m**	1.6 ± 0.6 m	2.4 ± 1.4 m	**2.0 m**
2019	1.2 ± 0.7 m	0.9 ± 0.3 m	**1.1 m**	1.2 ± 0.6 m	0.8 ± 0.7 m	**1.0 m**	1.1 ± 0.8 m	1.6 ± 1.1 m	**1.3 m**	2.1 ± 0.8 m	2.0 ± 0.7 m	**2.0 m**
2020	2.4 ± 1.0 m	3.1 ± 1.3 m	**2.7 m**	2.4 ± 1.0 m	3.1 ± 1.8 m	**2.7 m**	1.8 ± 1.2 m	1.7 ± 0.9 m	**1.8 m**	1.2 ± 0.7 m	1.2 ± 0.5 m	**1.2 m**
2021	0.7 ± 0.4 m	1.4 ± 1.8 m	**1.0 m**	0.7 ± 0.9 m	0.9 ± 0.4 m	**0.8 m**	0.9 ± 0.7 m	0.8 ± 0.8 m	**0.8 m**	2.7 ± 1.5 m	1.7 ± 0.5 m	**2.2 m**
2022	1.0 ± 0.6 m	1.0 ± 0.7 m	**1.0 m**	0.8 ± 0.8 m	2.1 ± 2.7 m	**1.4 m**	2.7 ± 1.5 m	2.4 ± 1.2 m	**2.5 m**	3.5 ± 1.6 m	3.2 ± 1.7 m	**3.4 m**
2023	0.4 ± 0.3 m	0.6 ± 0.4 m	**0.5 m**	1.9 ± 1.4 m	1.8 ± 1.2 m	**1.8 m**	2.7 ± 1.1 m	3.0 ± 1.7 m	**2.8 m**	2.2 ± 1.6 m	0.8 ± 0.7 m	**1.5 m**

Notes:
Avg = average
m = meter(s)

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Attachment A

Root River Pre- and Post-return Flow (2017-2023)
Wadeable Stream Macroinvertebrate Index of Biotic Integrity Summary

Root River pre-return flow and post-return flow (2017-2023) wadeable stream macroinvertebrate index of biotic integrity summary

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The wadeable stream macroinvertebrate index of biotic integrity is a multimetric index (M-IBI) calculated using linear combinations of component metrics that are regressed against empirical parameters for southeastern Wisconsin. The component metrics and index values used to calculate the M-IBI were reported and described in the Root River pre-return flow and post-return flow annual reports (Orlofske 2018, 2019, 2020, 2021, 2022, and 2023). The resulting M-IBI values are compared to a scale (Table 13. Wisconsin Consolidated Assessment and Listing Methodology (WisCALM) 2024) to determine the water quality rating for each sampling event.

The M-IBI scores among all sites and sampling events range from 0.1 (poor, Site A November, 2017; Site B September 2019; Site D November 2017) to 4.6 (fair, Site C November 2023; Table 1). All the M-IBI scores reported for these sites during this period were rated as either fair (21 instances, 36.2%) or poor (37 instances, 63.7%; Table 1). Downstream sites (Site C and Site D) received fair ratings more often (n=14) than upstream sites (Site A and Site B) during the same period (n=7; Table 1). In 2018, all sampling events received an M-IBI ratings of poor (Table 1). The greatest number of sampling events in a single year receiving a fair rating (n=4) occurred during the 2020, 2021, and 2023 survey periods (Table 1).

Overall, the M-IBI scores and ratings are consistent with the evaluation of the component metrics and index values described in detail in the Root River pre-return flow and post-return flow annual reports (Orlofske 2018, 2019, 2020, 2021, 2022, and 2023). Since the M-IBI is derived from these values, this consistency is expected. All of these measures indicate water quality impairment at all sites during each sampling event. As discussed in the Root River pre-return flow and post-return flow annual reports (Orlofske 2018, 2019, 2020, 2021, 2022, and 2023), natural fluctuations in benthic macroinvertebrate occurrence and abundance due to climate variability, particularly precipitation patterns, would contribute to the minor changes in scores among seasons and years.

Table 1: Wadeable stream macroinvertebrate index of biotic integrity summarizing metric and index values based on the macroinvertebrate samples collected from the Root River and Root River Canal locations (Sites A, B, C, and D), including field duplicates (FD), from September 2017 to November 2023. Ratings based on the Wisconsin Consolidated Assessment and Listing Methodology (WisCALM) 2024.

	-------- Site A -------		------------------ Site B -----------------			-------- Site C -------		------------------ Site D -----------------		
Year	**Sept**	**Nov**	**Sept**	**Nov**	**FD Nov**	**Sept**	**Nov**	**Sept**	**FD Sept**	**Nov**
2017	3.1 (fair)	0.1 (poor)	2.6 (fair)	1.4 (poor)	-	0.6 (poor)	3.1 (fair)	2.3 (poor)	-	0.1 (poor)
2018	2.2 (poor)	0.3 (poor)	1.7 (poor)	0.8 (poor)	-	1.9 (poor)	1.1 (poor)	2.4 (poor)	-	2.0 (poor)
2019	1.4 (poor)	3.1 (fair)	0.1 (poor)	1.6 (poor)	-	4.1 (fair)	2.4 (poor)	3.5 (fair)	-	1.6 (poor)
2020	3.3 (fair)	2.0 (poor)	1.0 (poor)	2.8 (fair)	-	1.8 (poor)	3.0 (fair)	2.4 (poor)	-	2.6 (fair)
2021	3.4 (fair)	0.8 (poor)	0.9 (poor)	1.4 (poor)	-	3.3 (fair)	3.2 (fair)	2.5 (fair)	-	1.0 (poor)
2022	1.5 (poor)	1.4 (poor)	0.9 (poor)	2.1 (poor)	-	3.1 (fair)	2.9 (fair)	3.8 (fair)	-	1.4 (poor)
2023	1.7 (poor)	0.6 (poor)	3.3 (fair)	1.8 (poor)	1.4 (poor)	3.3 (fair)	4.6 (fair)	2.9 (fair)	1.2 (poor)	2.0 (poor)