MMSD

PARTNERS FOR A CLEANER ENVIRONMENT

2016 Surface Water Quality Annual Summary Report

Freshwater Resources Monitoring Department

Background

The Federal Water Pollution Control Act of 1948, through amendments and revisions, became known as the Clean Water Act of 1972. This act mandates that all states have an Environmental Protection Agency (EPA) approved water quality protection process. In Wisconsin, the legislature has authorized the Department of Natural Resources (WDNR) to formulate and place into effect long-range water resources plans and set water quality standards, or criteria, for a given waterbody according to its highest potential use. In addition, the Southeastern Wisconsin Regional Planning Commission (SEWRPC) helps implement regional water quality plans as part of Section 208 of the Clean Water Act.

In 1979, the Milwaukee Metropolitan Sewerage District (the District) began its surface water quality monitoring program to comply with the Federal Water Pollution Control Act objectives and state water quality standards. The District also began its massive Water Pollution Abatement Program (WPAP) to eliminate bypassing and combined sewer overflows while improving and upgrading the District's two wastewater treatment facilities. As part of the WPAP, the Inline Storage System (ISS) was built and subsequently came online in 1994. At inception, the surface water quality monitoring program consisted of eight monitoring locations on the three major rivers (Milwaukee, Menomonee, and Kinnickinnic) and 11 monitoring locations on Lake Michigan.

Since that time, the District's surface water quality monitoring program has expanded to include greater spatial and temporal coverage. The program currently has 91 unique monitoring locations on 13 different rivers and creeks as well as Lake Michigan (Fig. 1). Two boats, the *Pelagos* and the *ORP*, are used to monitor the lake and the Milwaukee Estuary, while vans are used to sample the rivers, creeks, and upper estuary sites.

Introduction

The District's surface water quality monitoring program is required under the District's Wisconsin Pollutant Discharge Elimination System (WPDES) permit and the data are submitted annually to the WDNR. Monitoring requirements follow the Surface Water Quality Monitoring Plan (September 2011) and include the survey types listed in Table 1. In 2016, the District met all permit requirements in the Surface Water Quality Monitoring Plan.

In addition to being a permit requirement, other objectives of the surface water quality monitoring program include:

- Monitoring the biological, chemical, and physical characteristics of Lake Michigan and local waterways to assess the impact of District watercourse improvement projects, stormwater management rules, and nonpoint pollution prevention programs on water quality.
- Providing physical, chemical, and biological data on the quality of water, wastewater, and sediments to maintain and improve District operations and facilities and to satisfy external customer requests for related project data.
- Supplying water quality data interpretation and reports on environmental monitoring related to District operations and facilities planning.

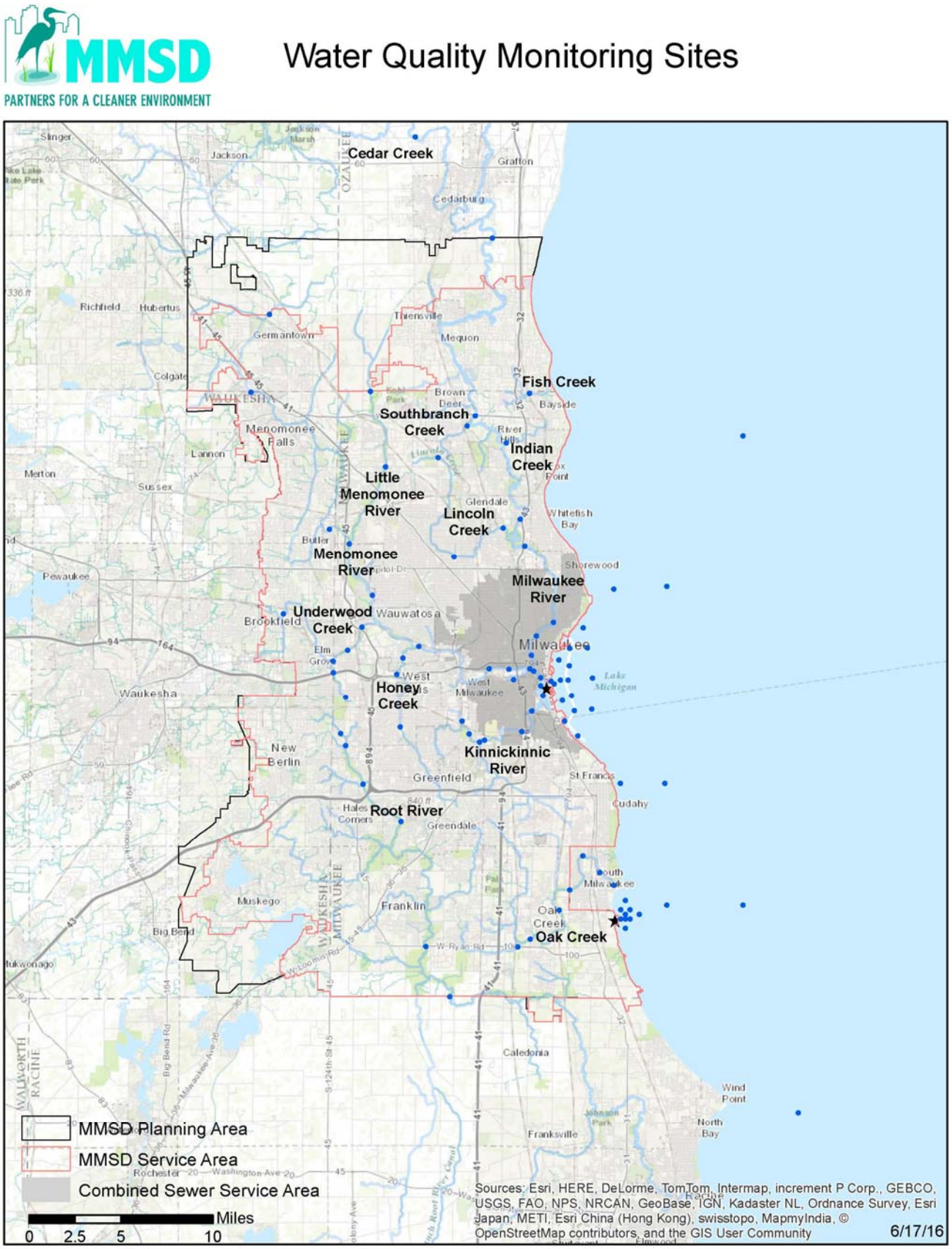

Figure 1: Map of all river, creek, and Lake Michigan monitoring sites.

- Maintaining a historical water quality database and providing this information to the public.
- Performing public education and outreach as it relates to the District's mission.

Table 1: Survey types and frequencies.

Survey Type	Number of Scheduled Surveys per Year	Number of Sampling Sites	Year Sampling Commenced
Nearshore	9	13	1979
Outer Harbor	14	16	1979
South Shore	14	9	1979
River	20	27	1980
Little Menomonee River	20	2	2007
Cedar Creek	20	1	2016
Indian Creek	9	1	2002
Southbranch Creek	9	1	1999
Lincoln Creek	9	3	1997
Underwood Creek	9	6	2003
Honey Creek	9	3	2001
Fish Creek	9	1	2002
Oak Creek	9	7	1985
Root River	9	6	1999
CP (dry, wet, CSO)	2 - 4	33	1995

Description of Surveys

Nearshore Survey

The purpose of this effort is to provide a database for the District to assess the impact of its discharges, as well as all other sources of pollution, including stormwater runoff, on nearshore water quality. Some Nearshore survey sampling sites are located a distance from shore to provide data for determining Lake Michigan background levels; these data have been useful in developing some of the District's effluent limitations and permit discharge fees. This survey covers the area of the nearshore environs of Lake Michigan from Fox Point on the north to Wind Point on the south and from the western shore of Lake Michigan to a point 10 miles east of the western shore. The total area of the lake covered by this survey is approximately 350 square miles.

Outer Harbor/South Shore Surveys

Water quality data from these two survey types are utilized to evaluate the impact that the Jones Island Water Reclamation Facility (WRF) and the South Shore WRF are having on Lake Michigan. The areas surrounding both WRF outfalls are intensively used for recreational boating and fishing. Sampling sites

for these surveys were selected based upon their position relative to the effluent outfalls and the movement of water (or currents) found in the areas. The site identified as OH-02 is the existing outfall for the Jones Island WRF. The site identified as SS-01 is the point of discharge from the South Shore WRF. A major drinking water plant intake (Oak Creek) is located approximately one mile southeast of SS-01. Water quality in both nearshore areas is also affected by the Milwaukee River as well as Oak Creek.

River Survey

Extensive monitoring of the three major river systems within the District's sewer service boundaries provides baseline data for measuring and documenting potential sources of pollution both inside and outside the District boundaries. The River survey helps document the benefits of the Deep Tunnel (ISS), watercourse improvement projects, nonpoint pollution prevention programs, and stormwater management plans. The Milwaukee River is the largest river within the District's service area and is currently recognized by community leaders as an important recreational water resource within the metropolitan area. The headwaters of the Milwaukee River originate in Fond du Lac County near Eden; the river enters the District planning area at Pioneer Road (County Trunk C) after passing through 86% of its drainage area. The main stem of the Milwaukee River totals 43.5 miles, and the Milwaukee River watershed covers 698 square miles. The Menomonee River watershed covers 136 square miles and is nearly 28 miles in length. The Menomonee River originates in a wetland area in the northeast corner of the Village of Germantown. Approximately 90% of the watershed is within the District's sewer service area. The Kinnickinnic River is located entirely within Milwaukee County and has a 26 square-mile drainage area. The Kinnickinnic River originates from a storm sewer at S. 60th Street and is eight miles long. The watershed is highly urbanized and, in contrast to the Milwaukee and Menomonee River basins, the Kinnickinnic watershed is completely serviced by sanitary sewers (i.e., there are no septic systems).

CP Survey

The CP survey, which is fundamentally similar to the River survey, is used to assess the impacts of a combined sewer overflow (CSO) and is sampled up to four times per year, under the following conditions: 1) in the event of a CSO (two surveys per year required if multiple occurrences); 2) when rainfall equals a minimum of 0.25" basin-wide and there is no CSO (wet CP survey); and 3) when there has been no rain for at least seven days with no CSO (dry CP survey).

Cedar Creek

A new sampling site was added to the surface water quality program in 2016 on Cedar Creek. Grab samples are obtained at this site twice per month, except in the winter (once per month).

A continuous water quality monitoring station was also installed in 2016 at the same sampling location on Cedar Creek. Continuous monitoring data are obtained through a submerged, multi-probe sonde which collects in situ measurements at 60-minute intervals, 24 hours per day, 365 days per year. Measured parameters include temperature, specific conductance, dissolved oxygen, and turbidity.

Cedar Creek Survey

Cedar Creek, which originates in Washington County from Big Cedar Lake, is a tributary to the Milwaukee River. Cedar Creek is 31.5 miles in length and it joins the Milwaukee River between the Village of Grafton and the City of Cedarburg. This creek has been impacted by many factors over the years, including numerous dams, PCB contamination, discharges from several WWTP's, industrial and dairy discharges, as well as rural and urban stormwater runoff.

Little Menomonee River Survey

The Little Menomonee River originates in southern Ozaukee County near Freistadt Rd. and flows in a mostly southerly direction for approximately 10 miles to its confluence with the Menomonee River near Highway 100 and Hampton Avenue. The Little Menomonee River subwatershed encompasses approximately 21.8 square miles, or nearly 16 percent of the Menomonee River watershed.

Honey Creek Survey

Honey Creek originates at the S. 43rd Street storm sewer outfall in the City of Greenfield and flows in a northerly direction for approximately 8.8 miles until its confluence with the Menomonee River in the City of Wauwatosa. The Honey Creek subwatershed encompasses 11 square miles. Channel modifications such as deepening, straightening, and lining with concrete have been made to 7.1 miles of Honey Creek. The creek flows under State Fair Park in an enclosed channel that consists of three 10 by 15 foot pipes. The Honey Creek subwatershed has experienced minor flooding problems, but the biggest problem with this creek has been the ecological degradation and habitat loss due to channel modifications.

Indian Creek Survey

Indian Creek is a tributary of the Milwaukee River located in northern Milwaukee County. The creek, 2.6 miles in length, originates in the Village of Bayside and has its confluence with the Milwaukee River just south of Bradley Road in River Hills. Large storms typically cause flooding in this watershed.

Fish Creek Survey

Fish Creek is located along the border between Milwaukee and Ozaukee Counties in the Village of Bayside and the City of Mequon. Fish Creek drains directly into Lake Michigan, approximately three miles downstream from the source. Major precipitation events result in rapid surface runoff to Fish Creek, thereby causing a flashy response in the creek, potentially causing flooding in the Village of Bayside.

Southbranch Creek Survey

Southbranch Creek, approximately 1.5 miles long, drains a three square mile area before it enters the Milwaukee River. Southbranch Creek originates from a storm sewer outfall located at about N. 58th St. and W. Bradley Rd. and the entire watershed lies in an urban setting. Southbranch Creek has a long history of flooding. In response to this flooding, the District, along with other concerned parties, implemented a flood management plan. The plan included removing houses from the floodplain as well as the installation of detention basins.

Lincoln Creek Survey

Lincoln Creek is approximately nine miles in length and drains a 21 square mile watershed. Lincoln Creek originates from a storm sewer outfall on N. 76th St., just north of W. Good Hope Rd. There is a history of having poor water quality and flooding problems due to urbanization within its watershed. In response to these problems, the District, along with other concerned parties, implemented a flood management plan which involved environmental restoration, creation of wetland stormwater detention areas, changes in creek channel morphology, stream bank erosion controls, and improvements in creek bed substrate.

Underwood Creek Survey

Underwood Creek originates in the City of Brookfield and flows approximately eight miles in a southeasterly direction to its confluence with the Menomonee River. The Underwood Creek subwatershed encompasses approximately 19.8 square miles and includes the Underwood Creek main stem, Dousman Ditch, and the South Branch of Underwood Creek. Much of Underwood Creek flows in a concrete-lined channel. Flooding problems have occurred in the subwatershed and sections of the creek have undergone flood management improvements.

Oak Creek Survey

Oak Creek flows into Lake Michigan about two miles north of the District's South Shore WRF. Knowledge of its water quality is helpful in determining impacts to the lake's nearshore zone. Oak Creek originates in the City of Franklin and is mainly comprised of stormwater runoff. It also receives flows from the North Branch of Oak Creek as well as the Mitchell Field Drainage Ditch. When monitoring began on Oak Creek, the area was primarily rural; since then, it has undergone significant development. Continued urbanization will increase the flows that this stream will be required to handle.

Root River Survey

The Root River drains approximately 197 square miles within Milwaukee, Waukesha, Racine, and Kenosha Counties. The watershed includes all, or portions of, 18 communities, and includes five sanitary sewer service areas. The Root River empties into Lake Michigan in the City of Racine. This survey covers the upper 72 square miles of the watershed located within the District's service area.

Whole Effluent Toxicity (WET) Testing

WET testing, also known as bio-monitoring, is a requirement of the WPDES permit for the District. Both JIWRF and SSWRF are subject to having their effluent periodically tested for potential toxicity to aquatic organisms. The two organisms utilized for our toxicity tests are *Ceriodaphnia dubia* (water flea) and *Pimephales promelas* (fathead minnow).

To date, JI and SS have passed all toxicity tests.

Water Quality Standards

In accordance with the Clean Water Act, each state is required to adopt water quality (WQ) standards and a plan of action for applying those standards. Waters are classified into different groups according to what they are or should be used for; these characteristics are then utilized in developing and establishing supportive standards for each classification. Water quality standards for a given body of water are set according to its highest potential use. Standards are used as a measuring stick or qualitative indicator of environmental characteristics of the water body that must be maintained if the water body is to be suitable for its specified use classification. Table 2 lists the surface water quality standards that are applicable to this report. If standards have not been developed, then guidelines are cited in the table.

Table 2: Applicable surface water quality standards and recommended guidelines.

Variable	Standard	Sampling Site
Dissolved Oxygen[1,2]	6.0 mg/L	OH sites 6,8,12,13,14. NS sites 1,2,3,4,5,7,8,10,11,14,27. All SS sites.
	5.0 mg/L	All FC, SB, RR, CC, and OC sites. The Milwaukee River above the North Ave. dam, the Menomonee River above the confluence with HC. OH sites 2,3,4,5,7,9,10,11,17,17. NS sites 12,13.
	2.0 mg/L	UC, IC, HC, LC, the KK River, the Menomonee River below the confluence with HC (RI sites 9,20,11,17), the Milwaukee River below the North Ave. dam (RI sites 6,7,8,15)(OH1/NS28), the South Menomonee Canal, and the Burnham Canal (RI site 31).
Fecal Coliform[1,2]	200 CFU/100 mL	All OH sites except OH 1. All NS sites except NS 28. All SS sites. All CC, FC, SB, RR, and OC sites. The Milwaukee River above the North Ave. dam (RI sites 1, 2, 3, 4, 5). The Menomonee River above HC confluence (RI 36, 16, 21, 22, 32).
	1000 CFU/100 mL	UC, IC, HC, LC, the KK River, the Menomonee River below the confluence with HC (RI Sites 9, 20, 11, 17), the Milwaukee River below the North Ave. dam (RI sites 6, 7, 8, 15)(OH 1/NS 28), the South Menomonee Canal, and the Burnham Canal (RI site 31).
pH[1]	6.0 – 9.0	All sites.
Specific Conductance[3]	150-500 µS/cm	All river and all creek sites within the Milwaukee River basin and the Milwaukee Estuary.
Total Ammonia Nitrogen[4]	3.09 mg/L	All sites.
Total Kjeldahl Nitrogen[5]	0.65 mg/L	All river and all creek sites.
Total Phosphorus[6]	0.007 mg/L	OH sites 6, 8, 12, 13, 14. NS sites 1, 2, 3, 4, 5, 7, 8, 10, 11, 14, 27. All SS sites.
	0.075 mg/L	All creek sites. River sites 36, 16, 21, 33, 34, 35. ML 1 and ML 2.
	0.1 mg/L	River sites, 1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14, 15, 17, 18, 19, 20, 22, 31, 32. OH sites 1, 2, 3, 4, 5, 7, 9, 10, 11, 15. NS sites 12, 13, 28.

Total Suspended Solids[7]	12 mg/L	All river and all creek sites within the Milwaukee River basin and the Milwaukee Estuary.
Turbidity[8]	5 NTU	All river and all creek sites.

1 WDNR. Chapter NR 102. Water Quality Standards for Wisconsin Surface Waters. NR 102.04. November 2010.
2 WDNR. Chapter NR 104. Uses and Designated Standards. NR 104.06. February 2004.
3 EPA. Volunteer Stream Monitoring: A Methods Manual. EPA 841-B-97-003. November 1997.
4 WDNR. Chapter NR 105. Surface Water Quality Criteria and Secondary Values for Toxic Substances. NR 105.06. July 2010.
5 EPA. Ambient Water Quality Criteria Recommendations. Information Supporting the Development of State and Tribal Nutrient Criteria. Rivers and Streams in Nutrient Ecoregion VII. December 2000.
6 WDNR. Chapter NR 102. Water Quality Standards for Wisconsin Surface Waters. NR 102.06. November 2010.
7 WDNR. Total Maximum Daily Loads for Total Phosphorus, Total Suspended Solids, and Fecal Coliform Milwaukee River Basin, Wisconsin. Draft Report. CDM Smith. July 2016.
8 University of Wisconsin. *Transparency, A Water Clarity Measure.* Water Action Volunteers, Volunteer Monitoring Factsheet Series, DNR PUB WT-755. 2010.

Fecal coliform standards are based on a geometric mean of five or more samples per month. One to two samples per month are collected at each monitoring site, but for the purposes of this report, the criteria are used as a benchmark of water quality and potential human health risk.

Methodology

Sample Collection

To get an overall assessment of a waterway's health, physical, chemical, and biological variables are analyzed as part of the District's surface water quality monitoring program (Table 3). Some variables are captured by sonde in situ (temperature, pH, specific conductance, dissolved oxygen, turbidity, and depth); remaining variables are run in-house by the District's Central Laboratory.

The monitoring program addresses, by random design, both dry and wet weather sampling periods. The sampling program is designed to not only capture both wet and dry events, but to be representative of the annual fluctuations in the number of wet and dry events each year. For example, during rainy years, a higher proportion of samples will be collected during rain events.

Sampling frequency varies by survey type. River, Outer Harbor, and South Shore samples are collected twice per month, while Nearshore and creeks are sampled once per month. River sites are sampled year-round; all other survey types are sampled March through November.

Exact sampling depths at any location may vary from year to year depending on lake levels, dam operations, seiches, and precipitation. Generally, three samples are collected at sites greater than four meters deep, i.e., one meter below the surface, one meter above the bottom, and mid-depth. Locations less than four meters deep are generally sampled at either two depths (i.e., one meter below the surface and one meter above the bottom) or one depth, depending on site conditions. Samples are collected from mid-channel, where feasible. Samples for metals testing are collected at mid-depth for sites greater than four meters deep and at the surface for shallower sites.

Data Verification (Quality Assurance)

After all laboratory analyses have been completed for a survey, Freshwater Resources Monitoring (FRM) staff and supervisor verify survey results (including quality assurance samples), according to established standard operating procedures. Data will be qualified with a Q flag if a known problem occurred during sample collection or handling, if a partial measure that is greater than 140% of the total (e.g., total soluble phosphorus is greater than 140% of total phosphorus), or if the data are identified as outliers. Data that were Q flagged were not included in this report.

Special Projects

The FRM department is periodically asked to assist with special projects such as sampling streambed sediments for PAH analysis with the USGS[1].

KK sediment sample

Unloading sediment from the Ponar sampler

Other recent projects include microplastics sampling with the USGS[2] and bacteriological sampling for UWM School of Freshwater Sciences[3].

Table 3: The District's surface water quality monitoring variable list.

Variable	Unit of Measure
1% Light Level	meters
Ammonia Nitrogen	mg/L
Biochemical Oxygen Demand (5 & 20 day)	mg/L
Chloride	mg/L
Chlorophyll *a*	mg/m^3
Depth	meters
Dissolved Oxygen	mg/L
***Escherichia coli* Bacteria**	MPN/100 mL
Fecal Coliform Bacteria	CFU/100 mL
Hardness	mg/L
Nitrate Nitrogen	mg/L
Nitrite Nitrogen	mg/L
Nitrate + Nitrite Nitrogen	mg/L
pH	Std. Units
Soluble Silica	mg/L
Specific Conductance	µS/cm
Temperature	°C
Total Alkalinity	mg/L
Total Arsenic	µg/L
Total Cadmium	µg/L
Total Calcium	mg/L
Total Carbon	mg/L
Total Chromium	µg/L
Total Copper	µg/L
Total Dissolved Organic Carbon	mg/L
Total Inorganic Carbon	mg/L
Total Kjeldahl Nitrogen	mg/L
Total Lead	µg/L
Total Magnesium	mg/L
Total Nickel	µg/L
Total Organic Carbon	mg/L
Total Phosphorus	mg/L
Total Selenium	µg/L
Total Silver	µg/L
Total Solids	mg/L
Total Soluble Phosphorus	mg/L
Total Suspended Solids	mg/L
Total Zinc	µg/L
Turbidity	FNU
Volatile Suspended Solids	mg/L
Water Transparency (Secchi Disk)	meters

Data Analysis

The Freshwater Resources Monitoring Department collected over 63,000 data points in 2016 from 91 unique sites (Fig. 1) for over 40 parameters (Table 3). All of the data generated are analyzed, but for the purposes of this report not all of the data are presented. To summarize this large data set, this report focuses on the analyses of selected parameters and sites which will be referred to as "focus sites". Further or additional data analysis using alternate methods or parameters can be provided based upon specific user requests.

Four parameters (total suspended solids, dissolved oxygen, total phosphorus, and fecal coliform) were analyzed for sites along the three major rivers (Milwaukee, Menomonee, and Kinnickinnic) as well as the Milwaukee Estuary and the Milwaukee Harbor. From each grouping, two "focus sites" were selected to highlight differences within a single river, harbor, or estuary section. The focus sites were selected based on percent of samples meeting water quality standards and/or site characteristics and were further analyzed for additional parameters. Boxplots (see Fig. 2 for example) were created for the additional parameters and grouped into categories representing nutrients, in situ measurements, and sewage indicators. The data were classified as good, fair, or poor according to water quality standards or guidelines for that site, where criteria or guidelines exist. If 75% or more of the data met the criterion for a parameter, the site was classified as having good water quality (green circle). If 50% - 75% of the data met the criterion for a parameter, the site was classified as having fair water quality (yellow triangle). If less than 50% of the data met the criterion for a parameter, the site was classified as having poor water quality (red square).

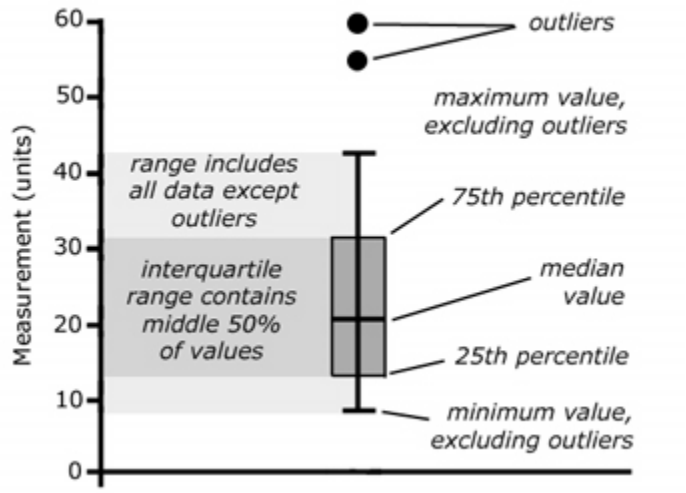

Figure 2: Diagram of a boxplot (Source: http://web.anglia.ac.uk).

Results: Milwaukee River

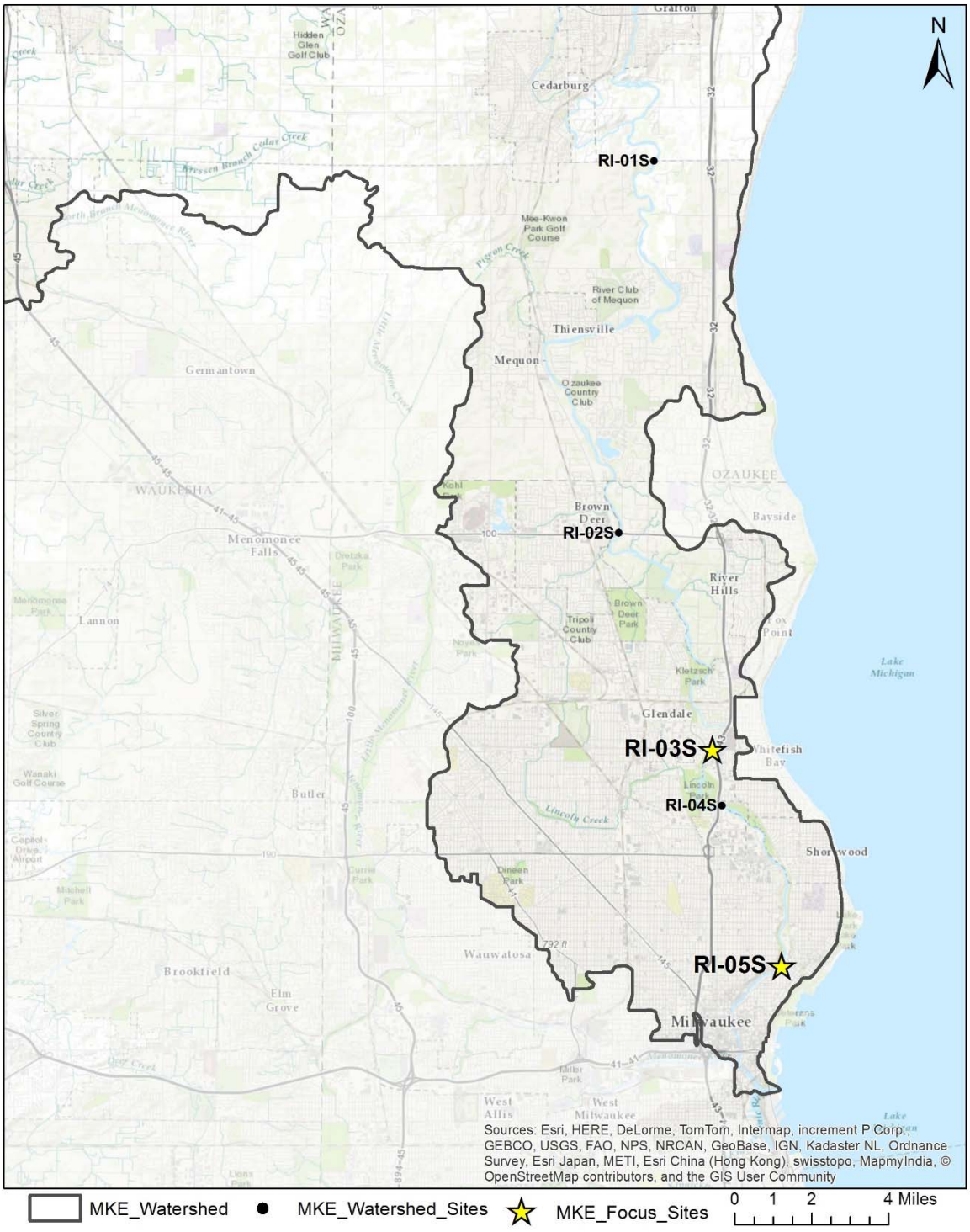

Figure 3: The Milwaukee River watershed with sampling sites.

The percent of samples meeting water quality standards was graphed for four parameters at sampling sites along the Milwaukee River upstream of the removed North Ave. dam (Fig. 4). The percent of samples where total suspended solids (TSS) met standards ranged from a high of 65% at RI-02 to a low of 35% at RI-05. Dissolved oxygen (DO) values met water quality standards for 100% of sites for all of 2016. The entirety of the Milwaukee River is under a variance for total phosphorus (TP), yet the percent of samples meeting water quality standards ranged between 45-50% at all sites. Fecal coliform (FC) results met the standard 50-60% of the time.

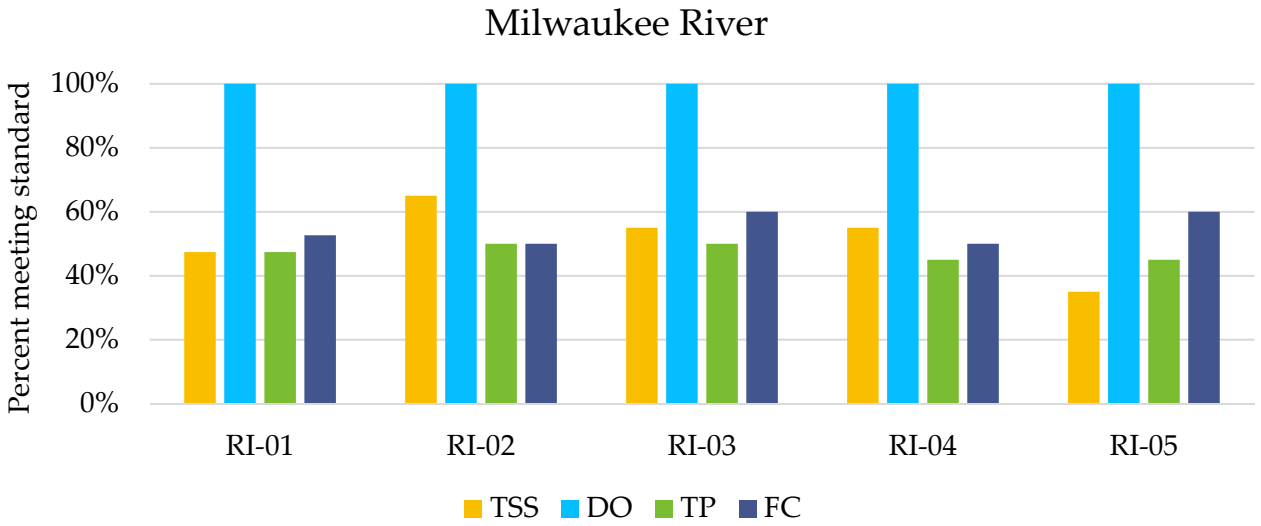

Figure 4: Percent of samples meeting standards for total suspended solids (TSS), dissolved oxygen (DO), total phosphorus (TP), and fecal coliform (FC) at Milwaukee River sites.

Two Milwaukee River focus sites were further analyzed: RI-03 and RI-05 (Fig. 3). Data collected from these sites reflect the free-flowing portion of the Milwaukee River. Site RI-05 is just upstream of the former North Avenue dam, where the Milwaukee Estuary begins, and is within the combined sewer area boundaries. Site RI-03 is located outside of the combined sewer area just upstream of the confluence of Lincoln Creek and the Milwaukee River. Both sites are highly urbanized and show a combined sewer area versus separated sewer area comparison.

Boxplots for 12 parameters from the 2016 data were created for these two sites (Figs. 5, 6, and 7); sample results were then compared to the standards/guidelines from Table 2. Tables were created displaying the percent of samples meeting water quality standards/guidelines (Tables 4, 5, and 6).

Nutrients - Milwaukee River Focus Sites RI-03 and RI-05

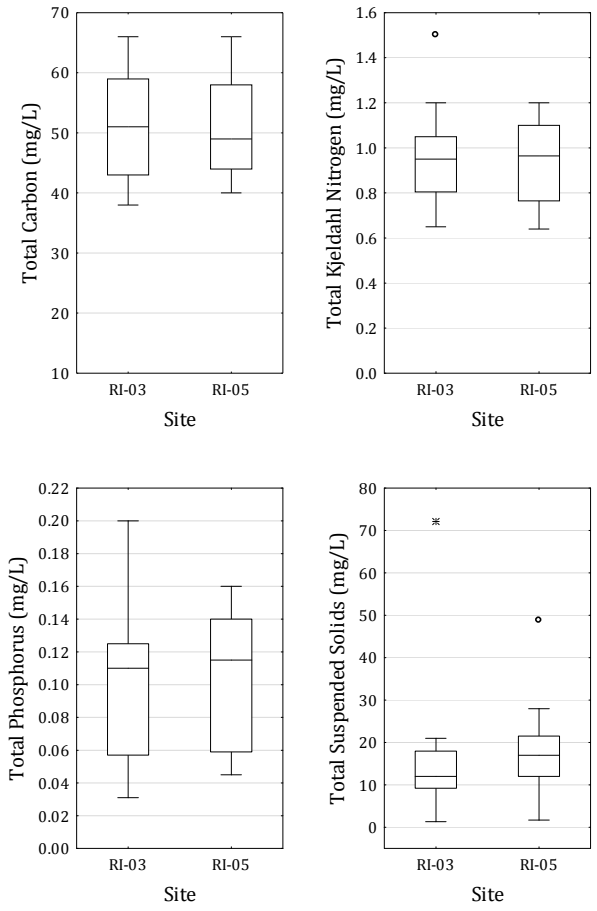

Figure 5: Nutrient concentration boxplots for Milwaukee River focus sites.

Although no criterion exists, total carbon (TC) results are relatively high for this section of the Milwaukee River when compared with other focus sites.

Sites RI-03 and RI-05 are not meeting the recommended criterion for total Kjeldahl nitrogen (TKN) for more than half of the samples (Table 4). Median values for this parameter are nearly 50% more than the recommended level (Fig. 5).

Table 4: Percent of samples meeting nutrient parameter standards for Milwaukee River focus sites.

Parameter (WQ criteria)	Site RI-03	Site RI-05
Total Carbon (None)	--	--
Total Kjeldahl Nitrogen (≤ 0.65 mg/L)	■	■
Total Phosphorus (≤ 0.1 mg/L)	▲	■
Total Suspended Solids (≤ 12 mg/L)	▲	■

● >75% ▲ 75-50% ■ <50%

For RI-03, water quality is rated as fair for TP and TSS, while for RI-05, water quality is rated as poor for TP and TSS. The Milwaukee River has a TP standard of 0.1 mg/L, yet median values are above the standard for both sites. Median values for TSS are also above the recommended criterion.

In Situ Parameters – Milwaukee River Focus Sites RI-03 & RI-05

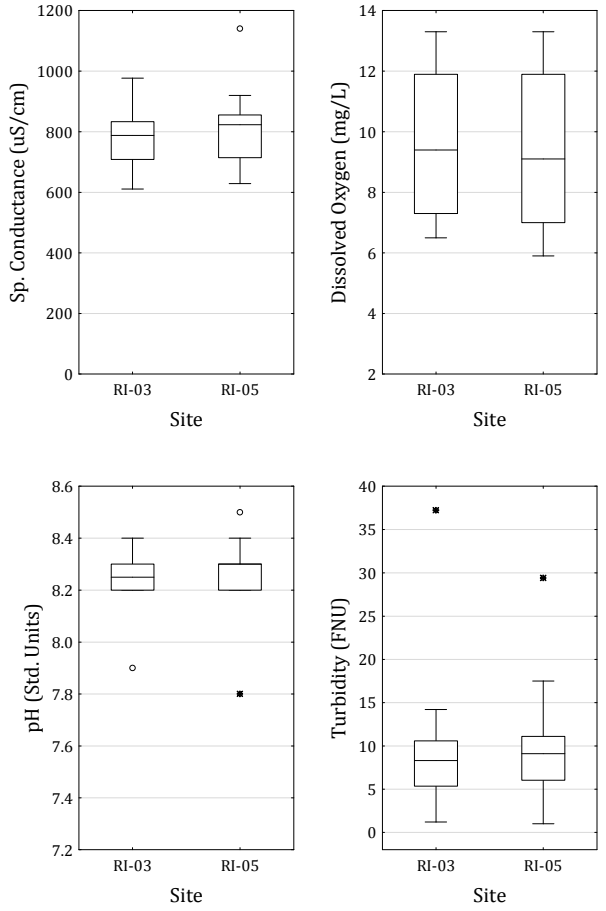

Figure 6: In situ parameter boxplots for Milwaukee River focus sites.

Sites RI-03 and RI-05 are meeting their standards for pH and DO for all of 2016 (Table 5).

Turbidity values for these two sites are infrequently below the 5.0 NTU recommended criterion (Fig. 6) and are meeting the criterion less than 20% of the time.

Table 5: Percent of samples meeting in situ parameter standards for Milwaukee River focus sites.

Parameter (WQ criteria)	Site RI-03	Site RI-05
Specific Conductance (150-500 µS/cm)	■	■
Dissolved Oxygen (≥ 5.0 mg/L)	●	●
pH (6.0-9.0 Std. Units)	●	●
Turbidity (≤ 5.0 NTU)	■	■

● >75% ▲ 75-50% ■ <50%

As with most sites within the sampling program, including RI-03 and RI-05, specific conductance values are elevated both during the winter as well as year-round. Both sites are well above the recommended guideline for specific conductance on all sampling dates.

Sewage Indicators – Milwaukee River Focus Sites RI-03 & RI-05

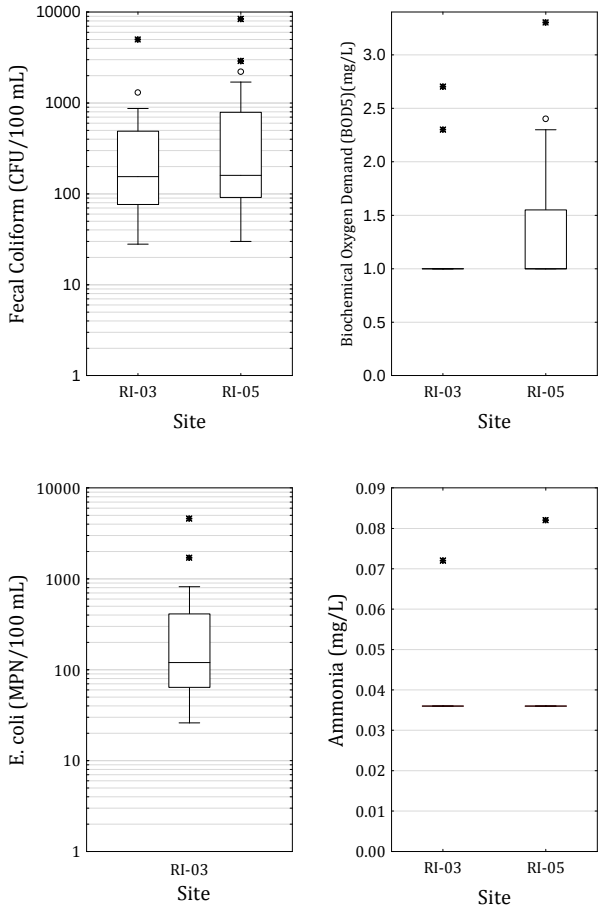

Figure 7: Sewage indicator parameter boxplots for Milwaukee River focus sites.

Ammonia has an excellent percentage for meeting water quality standards at these two sites (Table 6); almost all values fall below the detection limit of (0.076 mg/L).

Table 6: Percent of samples meeting sewage indicator parameter standards for Milwaukee River focus sites.

Parameter (WQ criteria)	Site RI-03	Site RI-05
Fecal Coliform (≤ 200 CFU/100 mL)	▲	▲
Biological Oxygen Demand (None)	--	--
E. coli (None)	--	--
Ammonia (≤ 3.09 mg/L)	●	●

● >75% ▲ 75-50% ■ <50%

Although there is no biological oxygen demand (BOD) standard, 5-day BOD values are low for these two sites with most values below 2.5 mg/L (Fig. 7).

Escherichia coli (E. coli) and fecal coliform values for these sites cover a wide range, with water quality for fecal coliform falling into the fair category for both sites. Samples from RI-05 are not tested for *E. coli* so only the RI-03 data are graphed (Fig. 7).

In summary for the Milwaukee River, RI-03 is rated poor for TKN, specific conductance and turbidity and rated fair for TP, TSS and fecal coliform. Site RI-05 is rated poor for TKN, TP, TSS, specific conductance and turbidity and rated fair for fecal coliform. Both sites are rated good for pH, DO and ammonia.

Results: Menomonee River

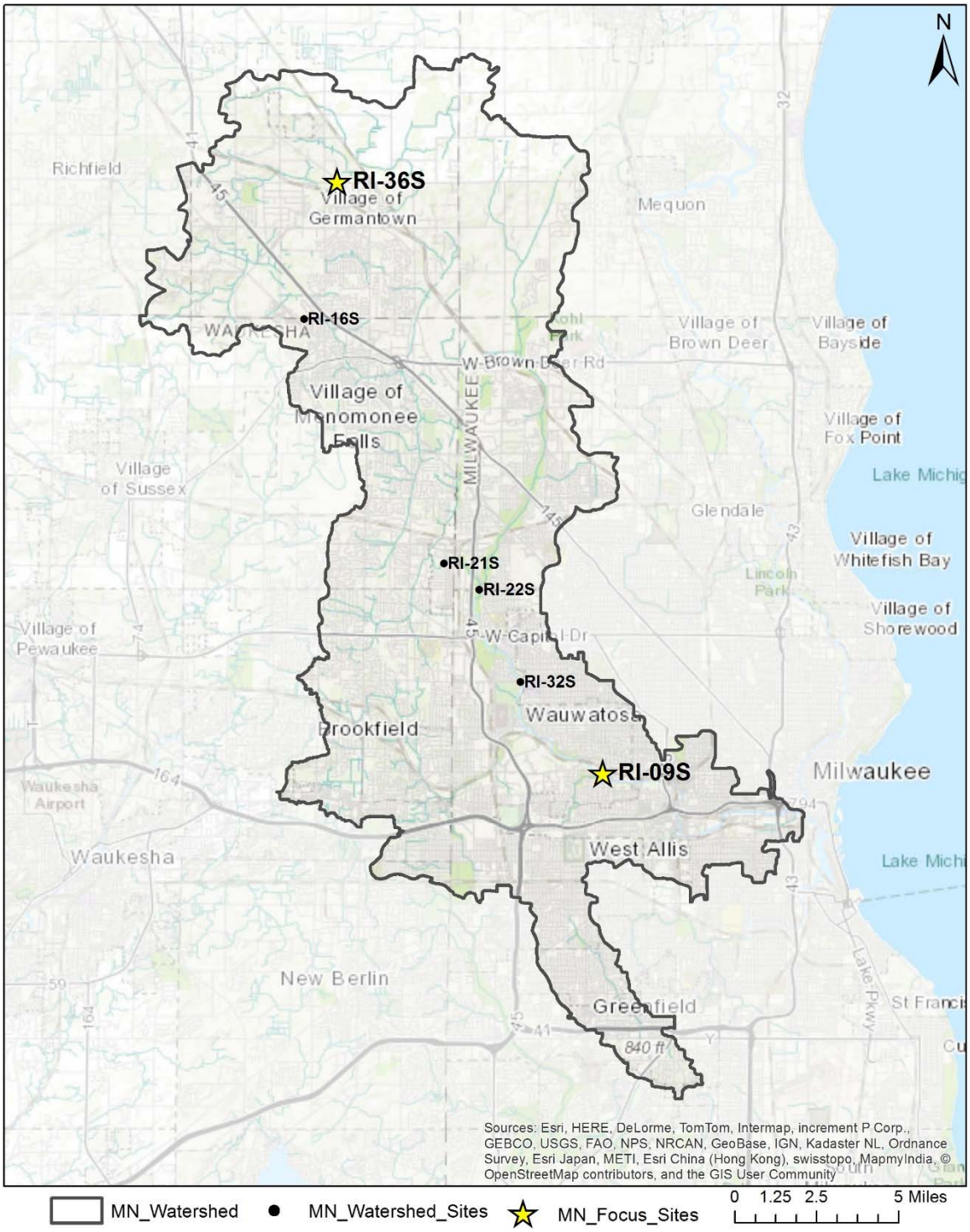

Figure 8: The Menomonee River watershed with sampling sites.

Along the Menomonee River, TSS met water quality standards 53-75% of the time (Fig. 9). Dissolved oxygen values met standards 80-100% of the time. For total phosphorus, the standard was met for 63% of the samples at RI-09 (the high), with 42% of the samples meeting the standard at RI-21 (the low). Fecal coliform values met the standard at RI-09 for 53% of the time, with only 42% of the samples meeting the standard at three other sites (RI-21, RI-22, and RI-32). Both TP and fecal coliform had results below the 50% meeting standards mark along the Menomonee River, even though RI-22 and RI-32 are under a TP variance, and RI-09 is under both a TP and fecal coliform variance.

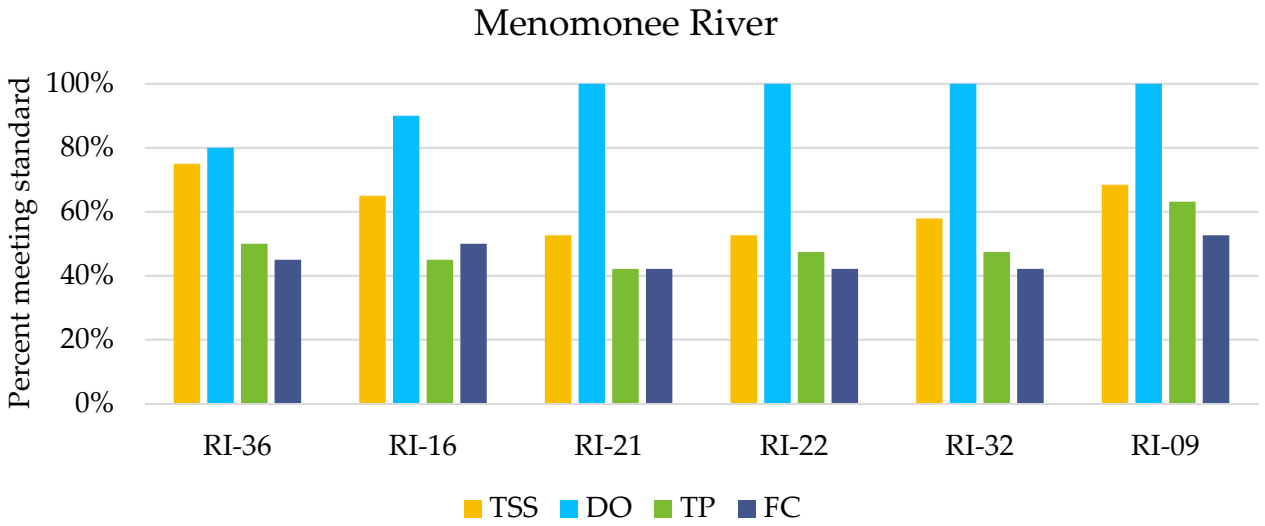

Figure 9: Percent of samples meeting standards for total suspended solids (TSS), dissolved oxygen (DO), total phosphorus (TP), and fecal coliform (FC) at Menomonee River sites.

Two Menomonee River focus sites were further analyzed: RI-36 and RI-09 (Fig. 8). The sites selected on this river system are located outside the combined sewer boundaries. Site RI-36 is in a more agricultural setting in the headwater of the river system. This site does not have the heavy urban impact that RI-09 has which is located just outside of the combined sewer area. While both sites are located outside of the combined sewer area, comparisons can be shown between the rural and urban sites featured.

Boxplots for 12 parameters from the 2016 data were created for these two sites (Figs. 10, 11, and 12); sample results were then compared to the standards/guidelines from Table 2. Tables were created displaying the percent of samples meeting water quality standards/guidelines (Tables 7, 8, and 9).

Nutrients – Menomonee River Focus Sites RI-36 & RI-09

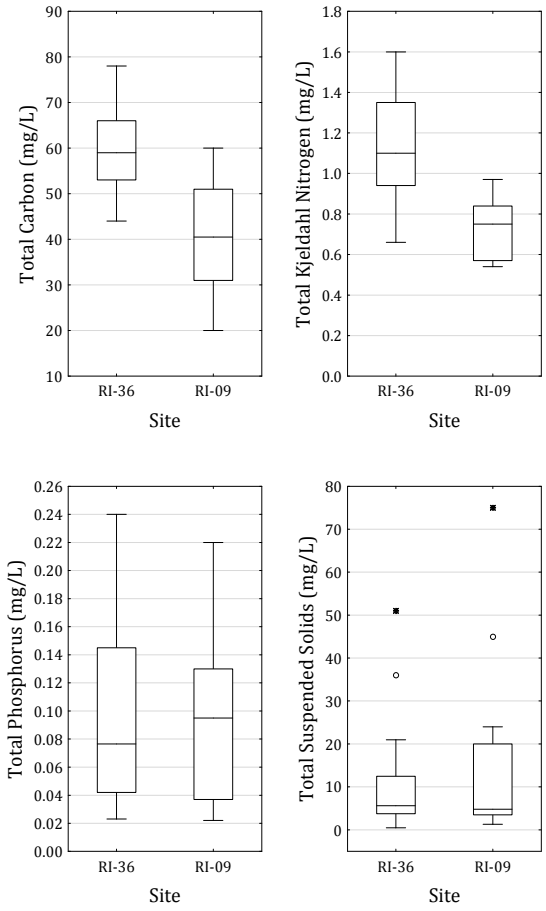

Figure 10: Nutrient concentration boxplots for Menomonee River focus sites.

As with the Milwaukee River focus sites, both focus sites on the Menomonee River are meeting the recommended criterion for TKN less than half of the time (Table 7). Like the upper Milwaukee River watershed, the headwaters of the Menomonee River are agriculturally influenced; this possibly contributes to the elevated TKN results, particularly at RI-36.

Table 7: Percent of samples meeting nutrient parameter standards for Menomonee River focus sites.

Parameter (WQ criteria)	Site RI-36	Site RI-09
Total Carbon (None)	--	--
Total Kjeldahl Nitrogen (≤ 0.65 mg/L)	■	■
Total Phosphorus (RI-36, ≤ 0.075 mg/L) (RI-09, ≤ 0.1 mg/L)	▲	▲
Total Suspended Solids (≤ 12 mg/L)	▲	▲

● >75% ▲ 75-50% ■ <50%

The value for TC at RI-36 is the highest of any of the focus sites (Fig. 10), with RI-05 and RI-03 having the next highest TC values (Fig. 5).

For TP and TSS, the percent of samples meeting the standards indicate fair water quality for both Menomonee River sites (Table 7). The upper portion of the Menomonee River has a TP standard of 0.075 mg/L (RI-36), while the lower Menomonee River has a standard of 0.1 mg/L (RI-09). Despite having a variance on the lower Menomonee River, the data are only meeting the standard 50-75% of the time.

In Situ Parameters – Menomonee River Focus Sites RI-36 & RI-09

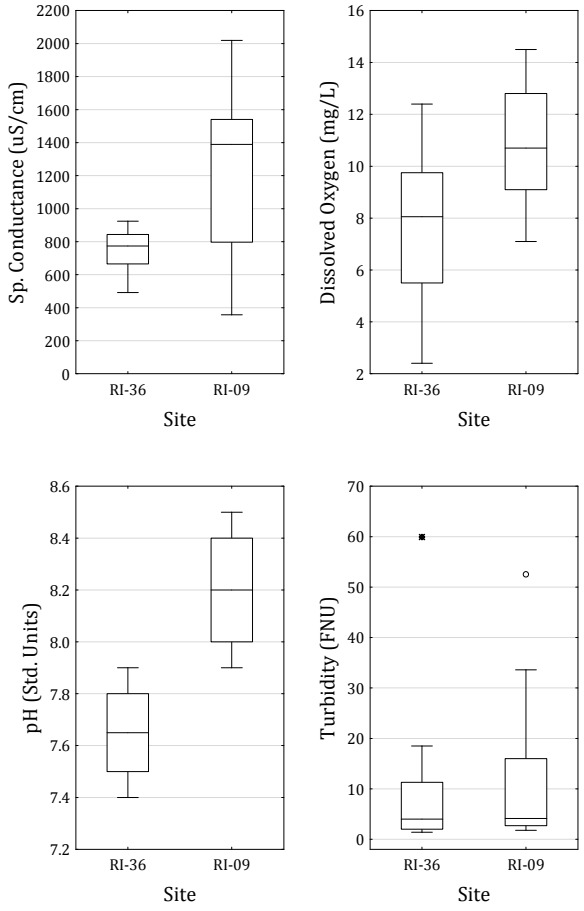

Figure 11: In situ parameter boxplots for Menomonee River focus sites.

Sites RI-36 and RI-09 are faring well for pH and DO; all pH results for both sites are within the limits of the standard while all DO results are above the 2.0 mg/L standard at site RI-09 (Fig. 11). The median value for DO at RI-36 is well above the standard; however, the lowest data point is below 3.0 mg/L. Note that the DO standard is higher for site RI-36 at 5.0 mg/L (Table 8).

Table 8: Percent of samples meeting in situ parameter standards for Menomonee River focus sites.

Parameter (WQ criteria)	Site RI-36	Site RI-09
Specific Conductance (150-500 µS/cm)	■	■
Dissolved Oxygen (RI-36, ≥ 5.0 mg/L) (RI-09, ≥ 2.0 mg/L)	●	●
pH (6.0-9.0 Std. Units)	●	●
Turbidity (≤ 5.0 NTU)	▲	▲

● >75% ▲ 75-50% ■ <50%

Specific conductance values for RI-36 are above the recommended guideline for nearly all samples, resulting in a poor water quality rating. Site RI-09 has most samples above the criterion, with the median value at nearly 1,400 µS/cm (Fig. 11), also resulting in a poor water quality rating for this parameter.

Median turbidity values are very close to the recommended guideline, resulting in a fair water quality rating for both Menomonee River sites.

Sewage Indicators – Menomonee River Focus Sites RI-36 & RI-09

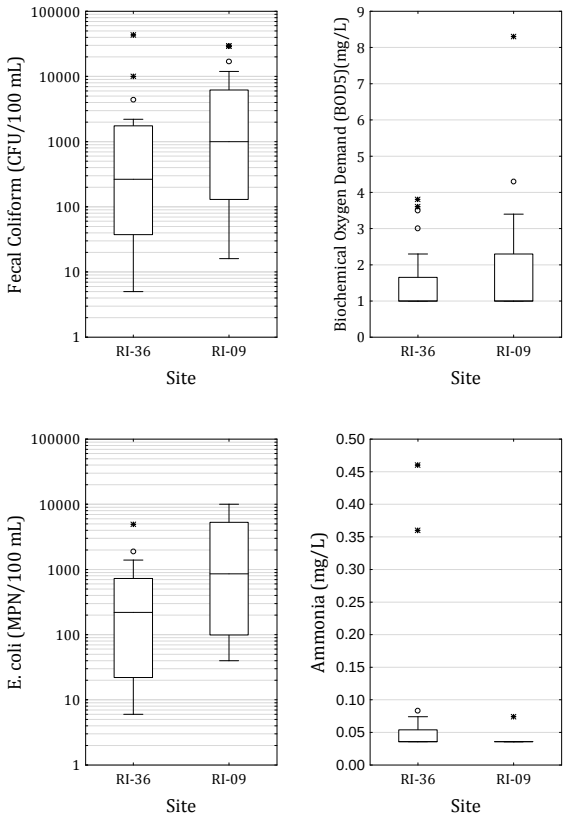

Figure 12: Sewage indicator parameter boxplots for Menomonee River focus sites.

Like the Milwaukee River, ammonia values for the Menomonee River focus sites are low and are classified as having good water quality for this parameter (Table 9).

BOD values at sites RI-36 and RI-09 are also low (Fig. 12); a water quality standard does not exist for this parameter.

Table 9: Percent of samples meeting sewage indicator parameter standards for Menomonee River focus sites.

Parameter (WQ criteria)	Site RI-36	Site RI-09
Fecal Coliform (RI-36, ≤ 200 CFU/100 mL) (RI-09, ≤ 1,000 CFU/100 mL)	■	▲
Biological Oxygen Demand (None)	--	--
E. coli (None)	--	--
Ammonia (≤ 3.09 mg/L)	●	●

● >75% ▲ 75-50% ■ <50%

Fecal coliform and *E. coli* results cover a wide range of values at these two sites and at times high readings are recorded, particularly at site RI-09, which is rated as having fair water quality for fecal coliform due to the standard variance of 1,000 CFU/100 mL. RI-36 is meeting its standard (200 CFU/100 mL) less than 50 % of the time and is classified as having poor water quality for this parameter.

In summary for the Menomonee River, RI-36 is rated poor for TKN, specific conductance and fecal coliform and is rated fair for TP, TSS and turbidity. Site RI-09 is rated poor for TKN and conductance and is rated fair for TP, TSS, turbidity and fecal coliform. Both sites are rated good for pH, DO and ammonia.

Results: Kinnickinnic River

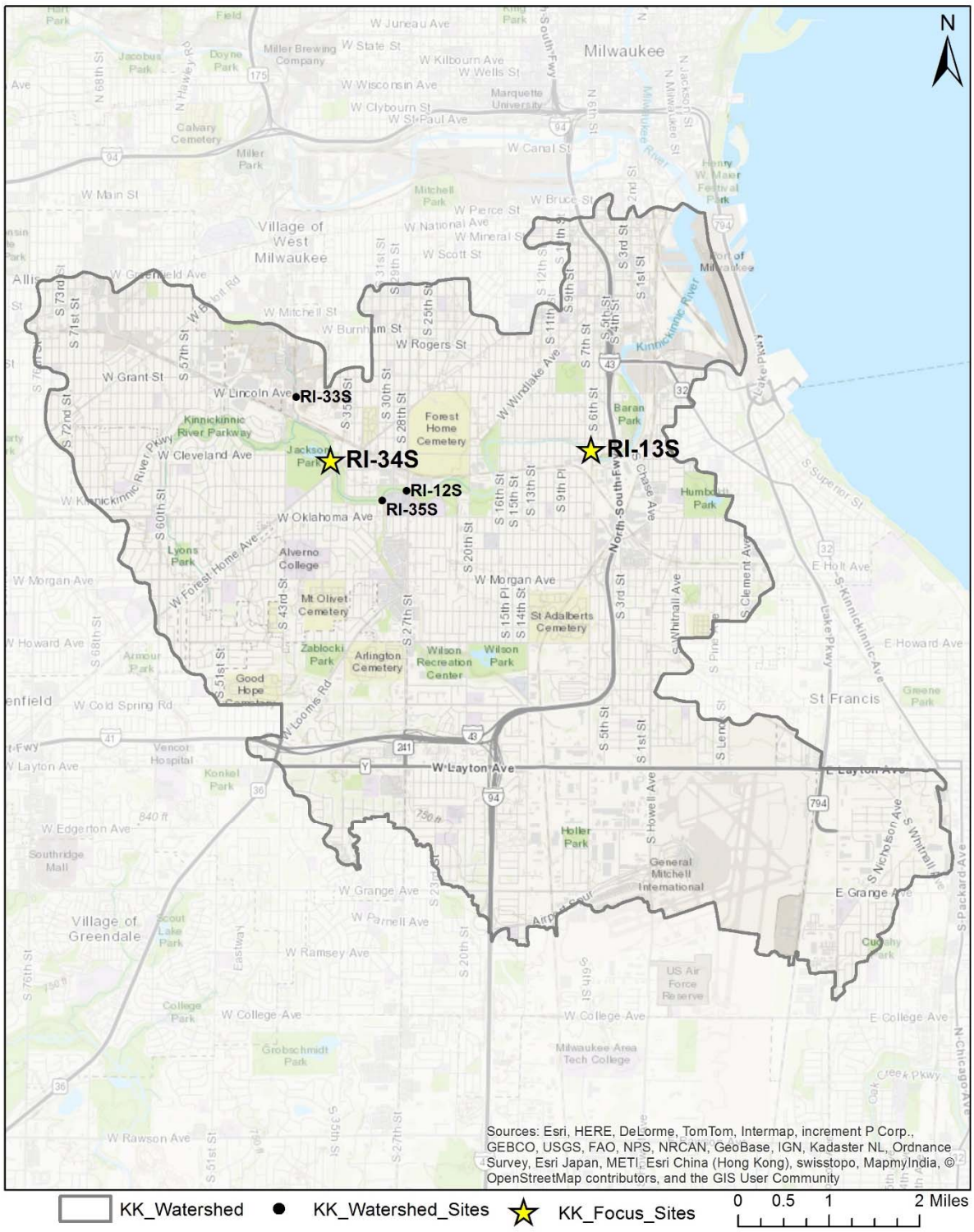

Figure 13: The Kinnickinnic River watershed with sampling sites.

On the Kinnickinnic River, TSS met the water quality standard 75% of the time at each site with a high of 90% while DO results met the standard for 100% of the samples at all sites (Fig. 14). For TP, both RI-33 and RI-34 met the standard 0% of the time while the remaining three sites met the standard between 63-74% of the time. Fecal coliform results for RI-34 only met the standard 45% of the time with RI-35 and RI-12 results staying at or below the standard for 63% of the samples.

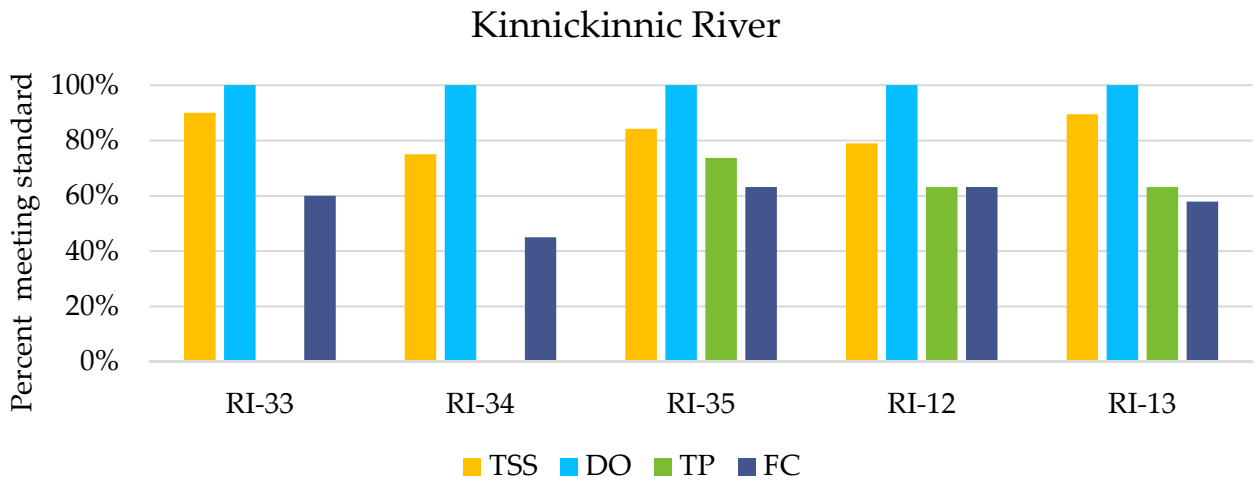

Figure 14: Percent of samples meeting standards for total suspended solids (TSS), dissolved oxygen (DO), total phosphorus (TP), and fecal coliform (FC) at Kinnickinnic River sites.

Two Kinnickinnic River focus sites were further analyzed: RI-34 and RI-13 (Fig. 13). The highly urbanized Kinnickinnic River has less potential for upstream erosion compared to the Milwaukee and Menomonee Rivers. The river is mainly concrete-lined upstream of 6th St. which likely results in fewer sediment inputs during storm events. Both sites are located outside the estuary and RI-34 is also located outside of the combined sewer area. Site RI-13 accounts for all the combined sewer area and non-CSO loading outside of the estuary. These sites show the comparison of a highly urbanized combined sewer area versus separated sewer river system.

Boxplots for 12 parameters from the 2016 data were created for these two sites (Figs. 15, 16, and 17); sample results were then compared to the standards/guidelines from Table 2. Tables were created displaying the percent of samples meeting water quality standards/guidelines (Tables 10, 11, and 12).

Nutrients – Kinnickinnic River Focus Sites RI-34 & RI-13

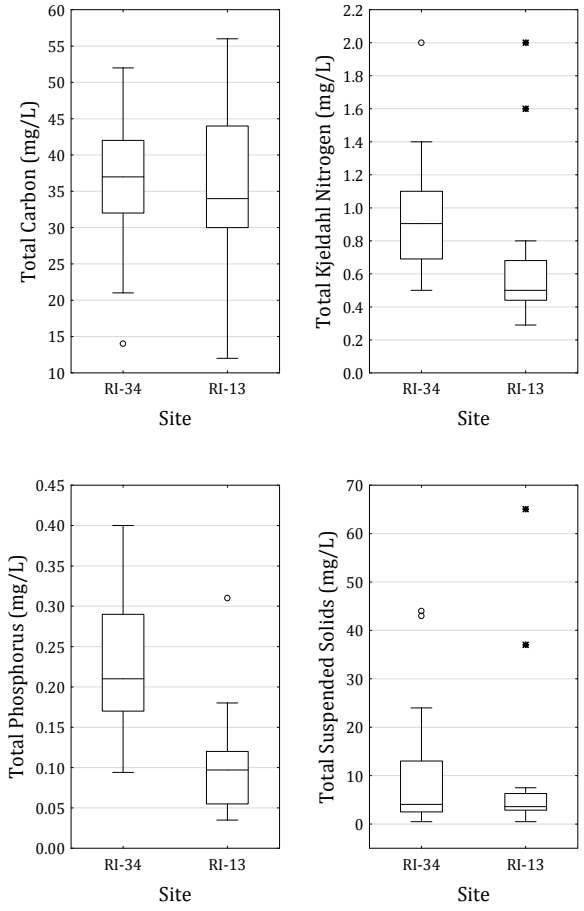

Figure 15: Nutrient concentration boxplots for Kinnickinnic River focus sites.

In contrast to the Milwaukee and Menomonee River sites, the Kinnickinnic River focus sites fall into the good water quality category for TSS (Table 10). Nearly all values for RI-13 fall below the standard, while the median for RI-34 is well below the standard (Fig. 15).

Site RI-34 did not meet its phosphorus standard at all in 2016, resulting in this site having a poor water quality rating for this parameter. Farther downstream on the Kinnickinnic, the standard for TP is higher (0.1 mg/L) which puts RI-13 into the fair water quality category. The median TP value for RI-13 falls just below the standard (Fig. 15).

Table 10: Percent of samples meeting nutrient parameter standards for Kinnickinnic River focus sites.

Parameter (WQ criteria)	Site RI-34	Site RI-13
Total Carbon (None)	--	--
Total Kjeldahl Nitrogen (≤ 0.65 mg/L)	■	▲
Total Phosphorus (RI-34, ≤ 0.075 mg/L) (RI-13, ≤ 0.1 mg/L)	■	▲
Total Suspended Solids (≤ 12 mg/L)	●	●

● >75% ▲ 75-50% ■ <50%

The Kinnickinnic River focus sites split on having poor and fair water quality ratings for TKN. The median value for RI-13 is just within the water quality standard range while the median value for RI-34 is nearly 50% greater than the standard value range (Fig. 15).

As our focus sites become more urban, the TC values continue to decline (Fig. 15). Carbon inputs upstream on the Menomonee and Milwaukee Rivers are much greater than they are on the concrete-lined Kinnickinnic River. Higher carbon inputs upstream are likely due to rural runoff, urban runoff, and other external organic inputs.

In Situ Parameters – Kinnickinnic River Focus Sites RI-34 & RI-13

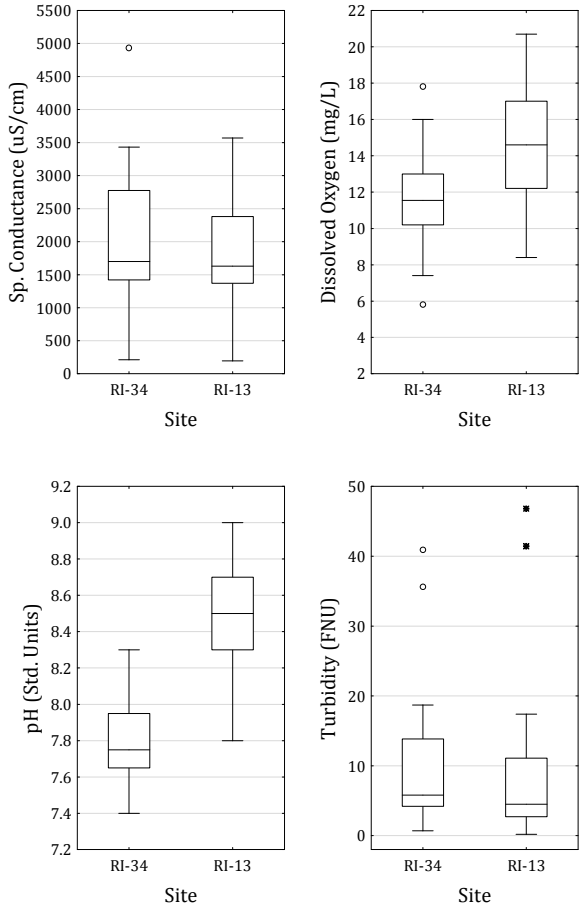

Figure 16: In situ parameter boxplots for Kinnickinnic River focus sites.

Median specific conductance values are extremely high for the Kinnickinnic River focus sites (Fig. 16) resulting in a poor water quality rating for this parameter at these two sites (Table 11).

Both DO and pH are meeting water quality standards and are classified as having good water quality for these two parameters.

Turbidity values at RI-34 are meeting the recommended guideline less than half of the time (Table 11); however, the median value is just slightly above the guideline (Fig. 16). Turbidity at RI-13 falls into the fair category with the median value very close to the standard. The range of 2016 turbidity data for both sites is very similar.

Table 11: Percent of samples meeting in situ parameter standards for Kinnickinnic River focus sites.

Parameter (WQ criteria)	Site RI-34	Site RI-13
Specific Conductance (150-500 µS/cm)	■	■
Dissolved Oxygen (≥ 5.0 mg/L)	●	●
pH (6.0-9.0 Std. Units)	●	●
Turbidity (≤ 5.0 NTU)	■	▲

● >75% ▲ 75-50% ■ <50%

Sewage Indicators – Kinnickinnic River Focus Sites RI-34 & RI-13

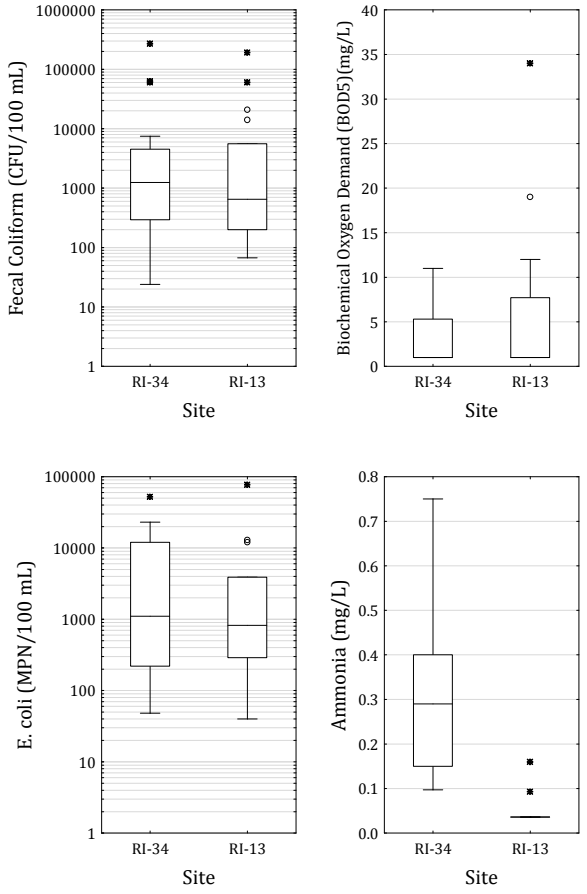

Figure 17: Sewage indicator parameter boxplots for Kinnickinnic River focus sites.

Both Kinnickinnic River focus sites are under a variance for fecal coliform. Site RI-34 is classified as having poor water quality, even with the variance (Table 12). Our other focus site, RI-13, is classified as having fair water quality regarding fecal coliform.

E. coli results can be high at these two sites (Fig. 17), with outlier values occasionally reaching over 10,000 CFU/100 mL.

Table 12: Percent of samples meeting sewage indicator parameter standards for Kinnickinnic River focus sites.

Parameter (WQ criteria)	Site RI-34	Site RI-13
Fecal Coliform (≤ 1,000 CFU/100 mL)	■	▲
Biological Oxygen Demand (None)	--	--
E. coli (None)	--	--
Ammonia (≤ 3.09 mg/L)	●	●

● >75% ▲ 75-50% ■ <50%

Values for BOD are generally low, but RI-13 can be impacted by deicing fluids during the winter months, causing the BOD levels to increase, at times, significantly.

All ammonia values at these two sites are well under the standard value and both sites are meeting the standard 100% of the time, giving these sites a good water quality rating for this parameter.

In summary for the Kinnickinnic River, RI-34 is rated poor for TKN, TP, specific conductance, turbidity, and fecal coliform with no parameters being rated as fair. Site RI-13 is rated poor for specific conductance and is rated fair for TKN, TP, turbidity, and fecal coliform. Both sites are rated good for TSS, pH, DO, and ammonia.

Results: Milwaukee Estuary

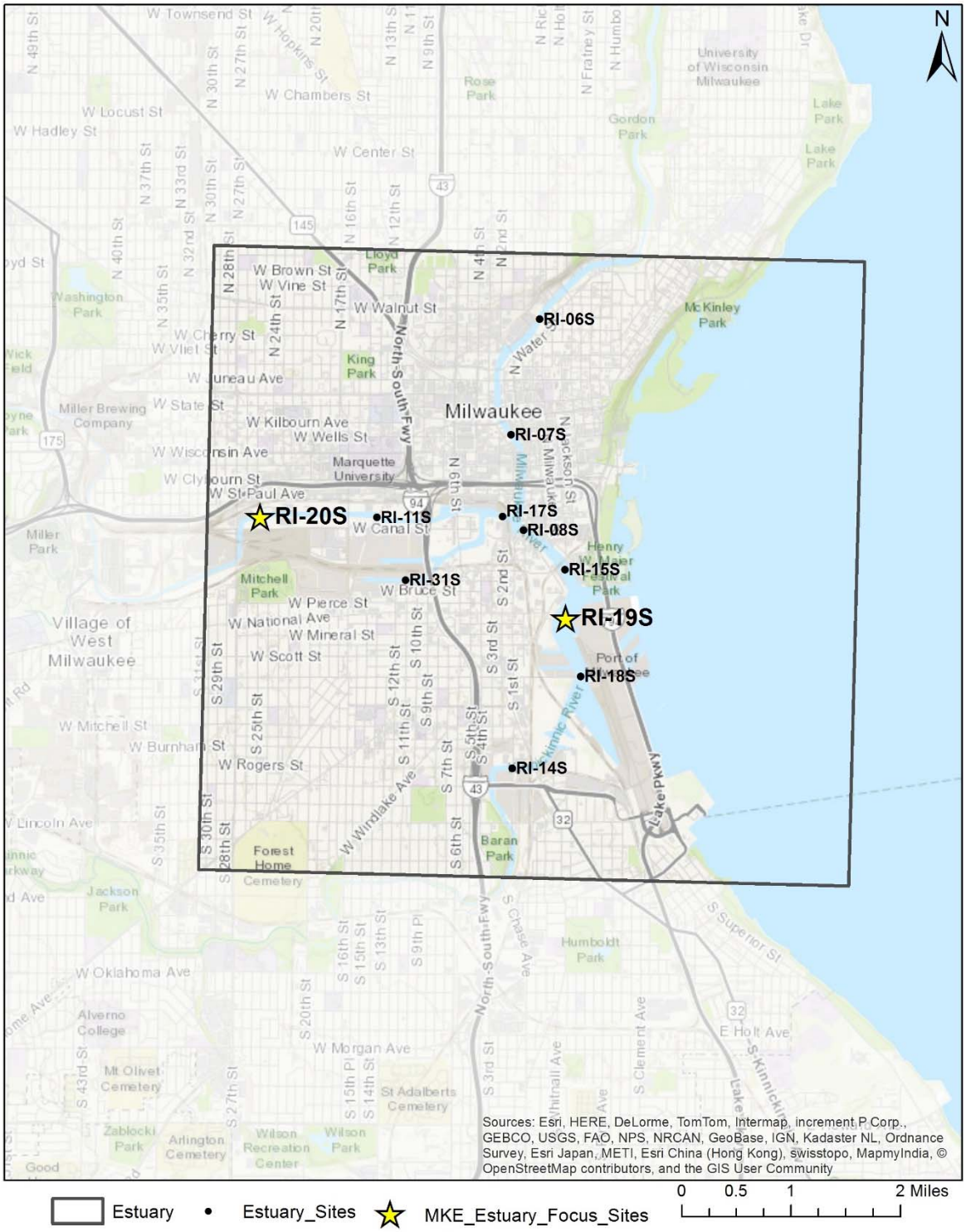

Figure 18: The Milwaukee Estuary with sampling sites.

The percent of samples meeting the standard for TSS at sites within the Milwaukee Estuary ranged from a low of 63% of the time on the Menomonee River (RI-20) to a high of 95% on the Burnham Ship Canal (RI-31) (Fig. 19). Only two sites did not meet DO standards 100% of the time: RI-14 (95%) and RI-11 (98%). For TSS, TP, and fecal coliform, RI-20 had the lowest percent of samples meeting the standards compared to any site in the estuary (63%, 37%, and 63%, respectively).

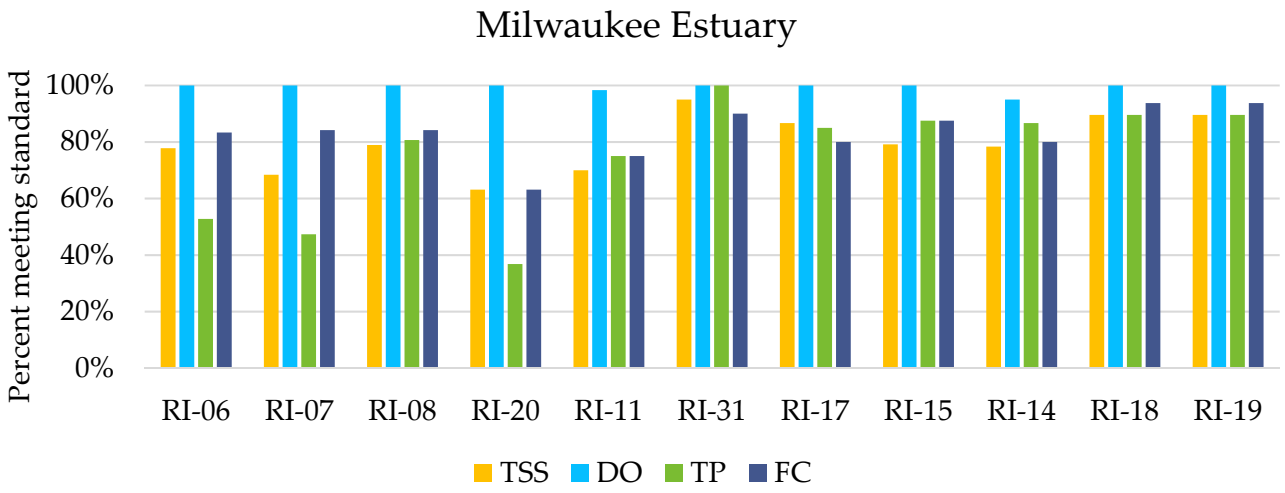

Figure 19: Percent of samples meeting standards for total suspended solids (TSS), dissolved oxygen (DO), total phosphorus (TP), and fecal coliform (FC) at Milwaukee Estuary sites.

Two Milwaukee Estuary focus sites were further analyzed: RI-20 and RI-19 (Fig. 18). Site RI-20 has historically been one of the worst sites in the estuary. It is located on the western edge of the estuary on the Menomonee River. Lake water intrusion does not have as great an effect on this site compared to RI-19. The Kinnickinnic River joins the Milwaukee River in the proximity of RI-19 and is highly influenced by Lake Michigan. This analysis compares a site with poor water quality to a site with relatively good water quality.

Boxplots for 12 parameters from the 2016 data were created for these two sites (Figs. 20, 21, and 22); sample results were then compared to the standards/guidelines from Table 2. Tables were created displaying the percent of samples meeting water quality standards/guidelines (Tables 13, 14, and 15).

Nutrients – Milwaukee Estuary Focus Sites RI-20 & RI-19

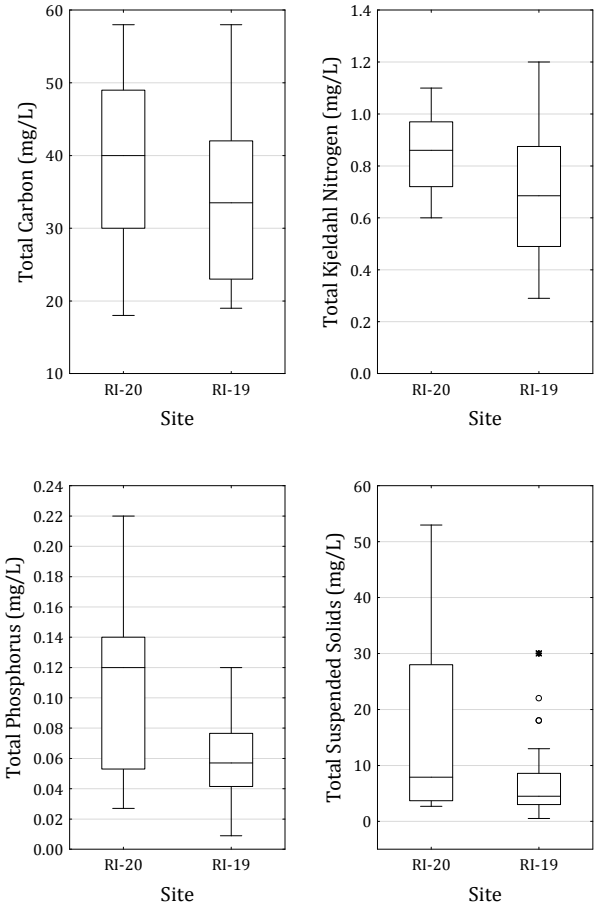

Figure 20: Nutrient concentration boxplots for Milwaukee Estuary focus sites.

Both RI-20 and RI-19 are failing to meet the criterion for TKN (Table 13). Nearly 85% of the samples for RI-20 have results higher than the criterion (0.65 mg/L), while 54% of RI-19 samples are above this criterion.

For TP, both sites fall under the 0.1 mg/L standard. The median value for RI-20 is just a little higher than the standard allows (Fig. 20), resulting in a poor water quality rating for this site. Conversely, RI-19 is meeting the standard most of the year, resulting in a good water quality rating for TP at this site.

Table 13: Percent of samples meeting nutrient parameter standards for Milwaukee Estuary focus sites.

Parameter (WQ criteria)	Site RI-20	Site RI-19
Total Carbon (None)	--	--
Total Kjeldahl Nitrogen (≤ 0.65 mg/L)	■	■
Total Phosphorus (≤ 0.1 mg/L)	■	●
Total Suspended Solids (≤ 12 mg/L)	▲	●

● >75% ▲ 75-50% ■ <50%

Sampling results for TSS range from fair water quality for RI-20 to good water quality for RI-19. The range of values is higher for RI-20 than for RI-19 while the median values are similar (Fig. 20). During storm events, sediment gets washed in from upstream and is carried out to the Milwaukee Harbor. The Menomonee River (RI-20) carries a larger sediment load (fair water quality for this parameter at RI-36 and RI-09), while the sites on the Kinnickinnic (RI-34 and RI-13) were rated as having good water quality for TSS, thus resulting in a rating of good for RI-19.

Values for TC within the estuary (Fig. 20) are similar to the values on the Kinnickinnic River focus sites. Since RI-19 is closer to the lake, and therefore more prone to mixing with and intrusions of lake water, its TC values are some of the lowest measured in the estuary.

In Situ Parameters - Milwaukee Estuary Focus Sites RI-20 & RI-19

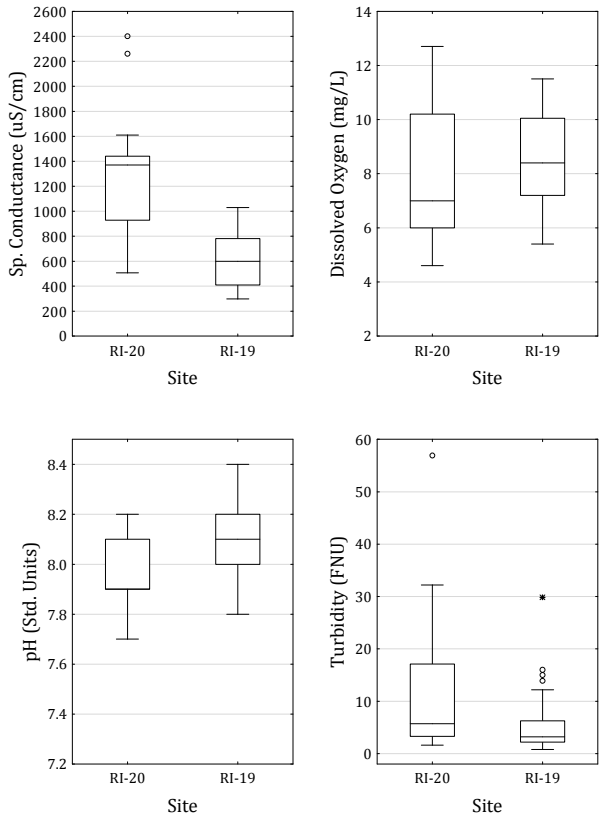

Figure 21: In situ parameter boxplots for Milwaukee Estuary focus sites.

Good water quality ratings for DO and pH continue into the estuary at sites RI-20 and RI-19. Note, however, that all estuary sites are under a variance for DO (2.0 mg/L) (Table 14).

All samples for 2016 resulted in pH readings within the standard's range of 6.0 to 9.0 Std. Units (Fig. 21).

Table 14: Percent of samples meeting in situ parameter standards for Milwaukee Estuary focus sites.

Parameter (WQ criteria)	Site RI-20	Site RI-19
Specific Conductance (150-500 µS/cm)	■	■
Dissolved Oxygen (≥ 2.0 mg/L)	●	●
pH (6.0-9.0 Std. Units)	●	●
Turbidity (≤ 5.0 NTU)	■	▲

● >75% ▲ 75-50% ■ <50%

As with all previous sites analyzed, results for specific conductance are above the recommended criterion at sites RI-20 and RI-19, resulting in a poor water quality rating for both sites (Table 14). All readings at RI-20 are above the recommended guideline, with the median value over 1,300 µS/cm (Fig. 21). For RI-19, some results were below the recommended guideline but the median value is still above the limit. Lake Michigan water is affecting the parameters at site RI-19, resulting in some lower readings for specific conductance.

Like TSS for RI-20 and RI-19 (Fig. 20), the range of values is larger for turbidity at RI-20 than at RI-19; however, median values are very close to each other (Fig. 21). Turbidity readings can be high at RI-20 during storm events. Results for turbidity at RI-19 are frequently affected by Lake Michigan water traveling upstream, resulting in a fair water quality rating for this site.

Sewage Indicators - Milwaukee Estuary Focus Sites RI-20 & RI-19

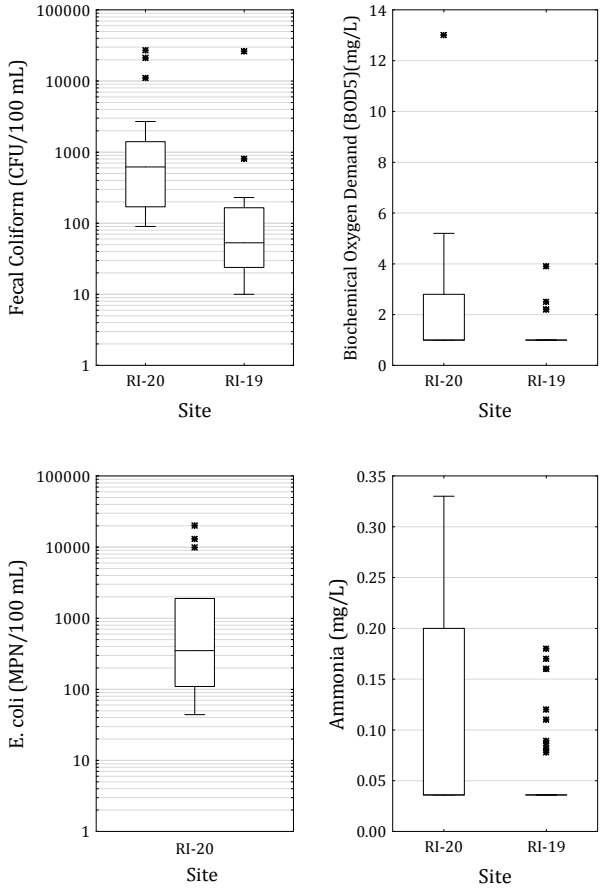

Figure 22: Sewage indicator parameter boxplots for Milwaukee Estuary focus sites.

Fecal coliform results are generally low at sites RI-20 and RI-19, with occasional outliers above 10,000 CFU/100 mL (Fig. 22). All estuary sampling sites fall under a fecal coliform variance (1,000 CFU/100 mL). Site RI-20 falls into the fair water quality category for fecal coliform while RI-19 is in the good water quality category (Table 15).

Samples are only tested for *E. coli* at site RI-20 so there are no *E. coli* results for RI-19 (Fig. 22). The range of data for *E. coli* at RI-20 spans from a low of 44 MPN/100 mL to a high of 20,000 MPN/100 mL.

Table 15: Percent of samples meeting sewage indicator parameter standards for Milwaukee Estuary focus sites.

Parameter (WQ criteria)	Site RI-20	Site RI-19
Fecal Coliform (≤ 1,000 CFU/100 mL)	▲	●
Biological Oxygen Demand (None)	--	--
E. coli (None)	--	--
Ammonia (≤ 3.09 mg/L)	●	●

● >75% ▲ 75-50% ■ <50%

BOD results are also generally low at these two sites, with one exception at RI-20 (13 mg/L) (Fig. 22). Nearly every BOD result at RI-19 was below the detection limit.

All ammonia results for both RI-20 and RI-19 are well below the standard (Fig. 22) and both sites are in the good water quality category for this parameter.

In summary for the Milwaukee Estuary, site RI-20 parameters were rated poor for TKN, TP, specific conductance, and turbidity while TSS and fecal coliform were rated fair. For site RI-19, TKN and specific conductance were rated poor and turbidity was rated fair. Site RI-20 was rated good for pH, DO and ammonia and RI-19 was rated good for TP, TSS, DO, pH, fecal coliform, and ammonia.

Results: Milwaukee Harbor

Figure 23: The Milwaukee Harbor with sampling sites.

Milwaukee Harbor sites had a high percentage of samples that met the standards for all parameters (Fig. 24), including the Jones Island outfall (OH-02). All harbor sites graphed below fall under a TP variance of 0.1 mg/L. Interestingly, fecal coliform results met the standard the lowest percentage of the time at OH-03, which is in the main channel just downstream of OH-01.

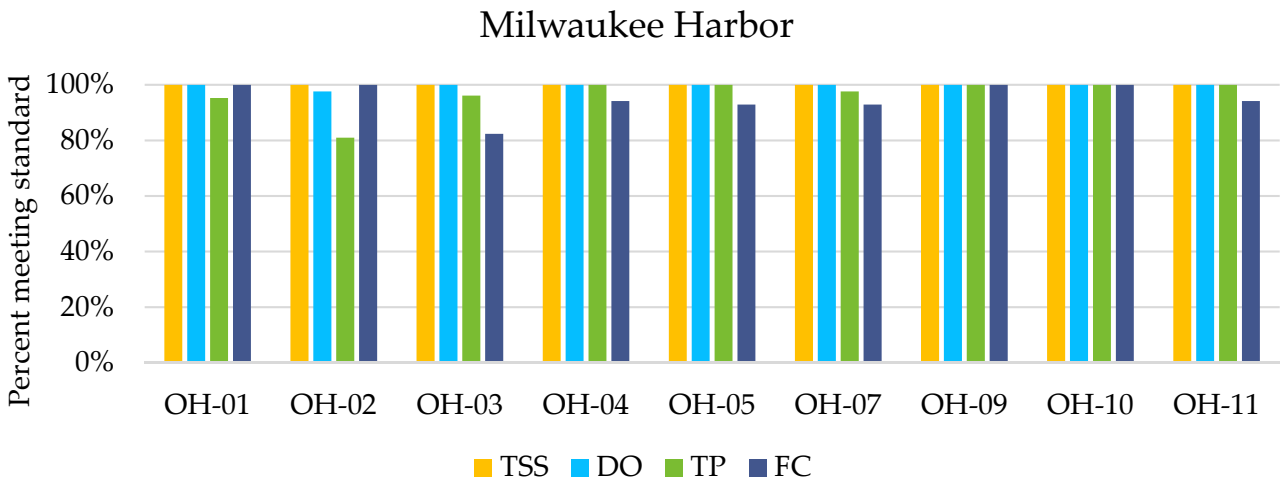

Figure 24: Percent of samples meeting standards for total suspended solids (TSS), dissolved oxygen (DO), total phosphorus (TP), and fecal coliform (FC) at Milwaukee Harbor sites.

Two Milwaukee Harbor focus sites were further analyzed: OH-01 and OH-07 (Fig. 23). Data collected from the Milwaukee Harbor are utilized to evaluate the impact that the Jones Island discharge is or is not having on the quality of this intensively used part of the lake. Due to the harbor breakwater, the water in the harbor is somewhat isolated from the open lake. Site OH-01 is at the river mouth and exhibits more similarities to a river site than an open lake site. Site OH-07, which is located within the main gap, has much more lake water influence.

Boxplots for 12 parameters from the 2016 data were created for these two sites (Figs. 25, 26, and 27); sample results were then compared to the standards/guidelines from Table 2. Tables were created displaying the percent of samples meeting water quality standards/guidelines (Tables 16, 17, and 18).

Nutrients – Milwaukee Harbor Focus Sites OH-01 & OH-07

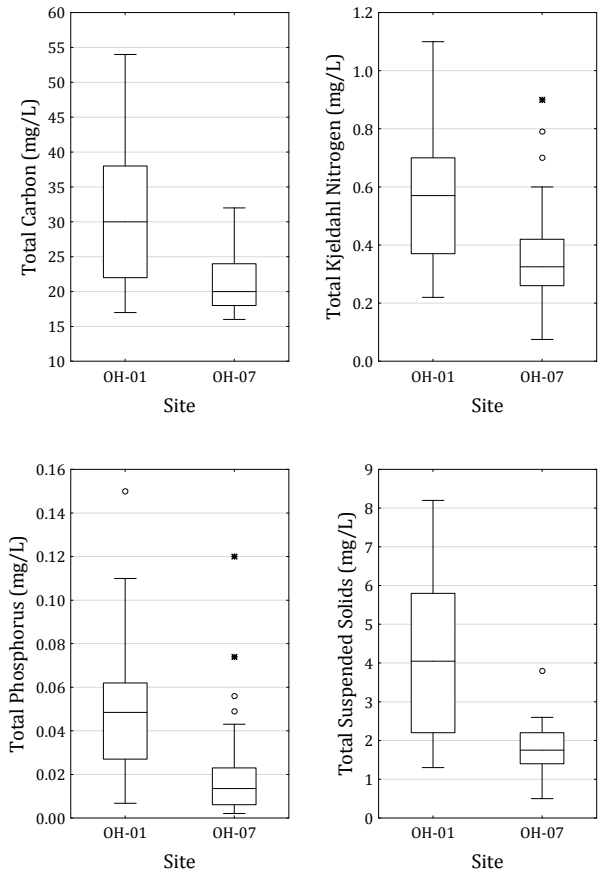

Figure 25: Nutrient concentration boxplots for Milwaukee Harbor focus sites.

The range of values at site OH-01 is larger for all parameters compared to OH-07 (Fig. 25). The resultant range of values for OH-07 is much narrower, due to the consistency of Lake Michigan water, compared to the highly variable water quality of a river site. In general, OH-07 has the lowest values for all parameters of all the focus sites, excluding DO which is much higher than the standard. Sites within the harbor breakwater are governed by a TP standard of 0.1 mg/L while the standard for the open lake is 0.007 mg/L. Medians for OH-01 and OH-07 are both well below the TP standard for the harbor. Both OH-01 and OH-07 are regularly meeting their water quality standards for TP. Site OH-01 also regularly meets the TSS standard (Table 16). Criteria do not exist for TC, TKN, or TSS for Lake Michigan sampling sites.

Table 16: Percent of samples meeting nutrient parameter standards for Milwaukee Harbor focus sites.

Parameter (WQ criteria)	Site OH-01	Site OH-07
Total Carbon (None)	--	--
Total Kjeldahl Nitrogen (None)	--	--
Total Phosphorus (≤ 0.1 mg/L)	●	●
Total Suspended Solids (OH-01, ≤ 12 mg/L) (OH-07, none)	●	--

● >75% ▲ 75-50% ■ <50%

In Situ Parameters - Milwaukee Harbor Focus Sites OH-01 & OH-07

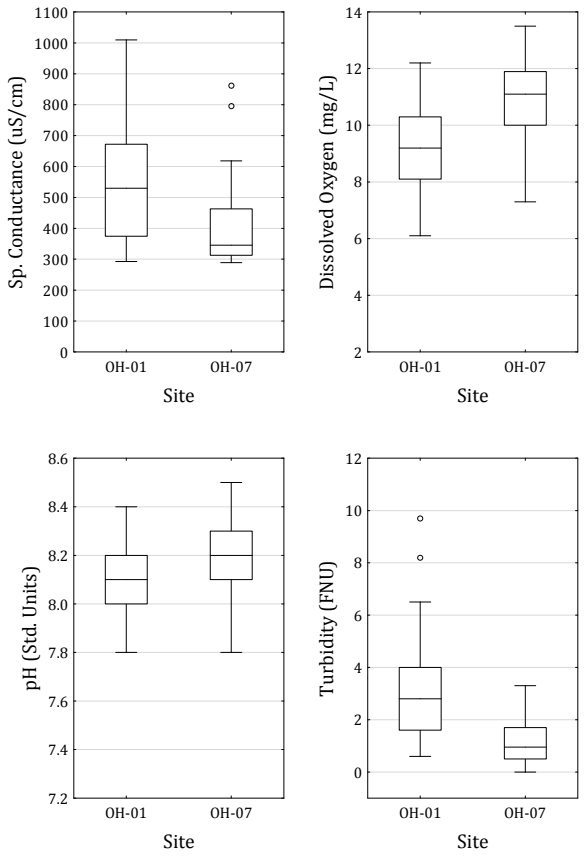

Figure 26: In situ parameter boxplots for Milwaukee Harbor focus sites.

Except for specific conductance, the difference in the range of values for these four parameters (Fig. 26) is not as pronounced as it was for the previous four parameters (Fig. 25). Turbidity, pH, and DO values all fall within a relatively narrow range for both OH-01 and OH-07. Additionally, both sampling locations meet standards for these three parameters a large percentage of the time. The median value for pH

Table 17: Percent of samples meeting in situ parameter standards for Milwaukee Harbor focus sites.

Parameter (WQ criteria)	Site OH-01	Site OH-07
Specific Conductance (None)	--	--
Dissolved Oxygen (OH-01, ≥ 2.0 mg/L) (OH-07, ≥ 5.0 mg/L)	●	●
pH (6.0-9.0 Std. Units)	●	●
Turbidity (≤ 5.0 NTU)	●	●

● >75% ▲ 75-50% ■ <50%

for both sites falls within the standard range. Median values for DO are above the standard for both sites and the median values for turbidity are below the recommended criterion for both sites (Fig. 26).

There is no water quality criterion for specific conductance in Lake Michigan (Table 17); however, the range of values for OH-01 goes above 1,000 uS/cm with a median value above 500 uS/cm. These values are high compared to the values observed outside of the breakwater or even at OH-07. Site OH-01 is directly impacted by the discharge of all three rivers (Milwaukee, Menomonee, and the Kinnickinnic). Site OH-07 is also impacted by the discharge from the rivers, but is more heavily influenced by Lake Michigan water.

Sewage Indicators - Milwaukee Harbor Focus Sites OH-01 & OH-07

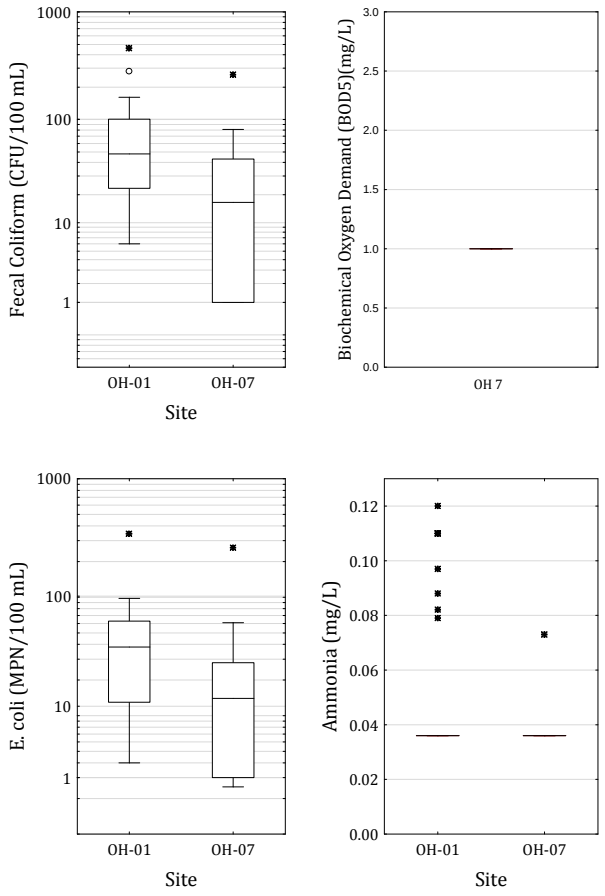

Figure 27: Sewage indicator parameter boxplots for Milwaukee Harbor focus sites.

As with all the focus sites in this report, ammonia values are meeting the ammonia standard greater than 75% of the time, giving OH-01 and OH-07 a rating of good water quality (Table 18). Most data points were below the method detection limit (MDL) for these two sites (Fig. 27).

Fecal coliform and *E. coli* results were good with the standard for fecal coliform being met greater than 75% of the time at both sites. There is no standard for *E. coli*, but all sampling results were below 100 MPN/100 mL apart from one outlier at each site (Fig. 27). Median values for these

Table 18: Percent of samples meeting sewage indicator parameter standards for Milwaukee Harbor focus sites.

Parameter (WQ criteria)	Site OH-01	Site OH-07
Fecal Coliform (≤ 200 CFU/100 mL)	●	●
Biological Oxygen Demand (None)	--	--
E. coli (None)	--	--
Ammonia (≤ 3.09 mg/L)	●	●

● >75% ▲ 75-50% ■ <50%

two parameters indicate good water quality at these sites.

Results for BOD were below the MDL for OH-07. This parameter is not sampled at OH-01. There is no standard or criterion for BOD.

In summary for the Milwaukee Harbor, both sampling sites are doing well regarding meeting their standards/criteria. Both sites were rated as having good water quality for the parameters that have standards or criteria.

Discussion

Nutrients

Nearly all sites were rated poorly for TKN except for one site on the Kinnickinnic River, which received a fair rating. Total Kjeldahl nitrogen is a combination of organic nitrogen and ammonia. Organic nitrogen is contained in compounds such as amino acids, proteins, urea, and polypeptides. Sources of organic nitrogen include phytoplankton, zooplankton, fish, runoff from farmland and barnyards, sewage, and industrial waste effluent. The decomposition of organic nitrogen consumes dissolved oxygen from the aquatic system; large quantities of organic nitrogen can cause an increase in BOD with a corresponding decrease in DO levels.

Carbon is an essential building block for all forms of life. Total carbon is a measure of both organic and inorganic carbon and can be used as an overall measure of the productivity of a waterbody. While there is no standard for TC, a decreasing trend in TC from the upper reaches of the Milwaukee and Menomonee Rivers to Lake Michigan is observed. One important component of TC is algal biomass; large quantities of algae can greatly increase carbon inputs and thereby decrease dissolved oxygen levels. The decomposition of algae consumes oxygen, as does algal respiration. Other sources of carbon would include urban and rural runoff, municipal sewage effluents, industrial effluents, and other external inputs (leaves and other organic material).

Much of the upper Milwaukee River watershed is agriculturally influenced, potentially contributing sediment during storms as well as phosphorus which is bound to the sediment. Phosphorus attaches to soil particles, thus entering the water body during storm runoff events. Sources of phosphorus include fertilizers, manure, organic wastes in sewage, and industrial effluent. Excess phosphorus can lead to eutrophication of a water body, resulting in algal blooms, hypoxia, and fish kills. Water quality ratings for TP were mixed, with three sites each rated as good and poor, and four sites as fair.

Four focus sites each were rated as good and fair, with only one site poor with regards to TSS. Nutrients, pesticides, and other potentially toxic materials (e.g., heavy metals) are both adsorbed onto and absorbed by suspended solids. Additionally, excessive amounts of suspended solids can reduce spawning habitat, smother fish eggs, clog the gills of fish, and affect the ability of invertebrates to filter feed. Eliminating stream bank erosion and installing riparian borders will help curb suspended solids entering our rivers and streams, thereby also decreasing nutrient inputs as well as other chemicals.

In Situ Parameters

The data analyzed in this report indicate a chronic problem concerning specific conductance. All focus sites were rated poor for specific conductance, except for OH-01 and OH-07 (no water quality criterion exists for the harbor or lake sites). Additionally, median values were, at times, over double the recommended level for this parameter. Specific conductance can be directly related to chloride values. Increasing chloride values are mainly due to de-icing practices during the winter months[4]. Chlorides can become trapped in the adjacent soil resulting in increased chlorides throughout the year. Rain events continue to wash the chlorides into the waterway throughout the summer, yet each year the quantity of chlorides in the soil increases from de-icing practices[4].

Conversely, all focus sites, including the harbor sites, were rated as having good water quality for DO and pH. The dissolved oxygen content is an indication of the status of the water with respect to the balance

between oxygen consuming and oxygen producing processes at the moment of sampling. Inputs of organic and inorganic material from combined sewer overflows, bypasses and wastewater treatment plant operations, the decomposition of in-place sediments, and respiration of aquatic organisms can significantly deplete the DO levels in the water. Diurnal fluctuations, particularly during the summer months, are common for most streams and river systems.

pH, which is the measure of hydrogen ion activity, is an important factor in the chemical and biological systems of natural water. The degree of dissociation of weak acids or bases is affected by changes in pH. This effect is important because the toxicity of many compounds (i.e., un-ionized ammonia, cyanide, and heavy metals) are affected by the degree of dissociation.

Turbidity is used as a measure of water clarity or clearness. Only two sites were classified as good, with the remaining split evenly with four each as fair and poor. Water that is excessively turbid can affect drinking water, aquatic plant life, fish, aquatic insects, and other invertebrates (freshwater mussels and other filter feeders). Large amounts of suspended solids (TSS) in the water leads to high turbidity values. When water is highly turbid, sunlight is unable to penetrate the lower depths influencing aquatic plant life. Turbid water also makes it more difficult for fish to find food and for invertebrates to filter food out of the water. Highly turbid water is also more difficult to treat at drinking water plants.

Sewage Indicators

Ammonia nitrogen can be toxic to fish and other aquatic life in its un-ionized form. Ammonia nitrogen also acts as a readily assimilable nutrient source for aquatic plant growth and is also an oxygen demanding substance in aerobic environments. Inputs of ammonia to the aquatic environment include domestic and industrial wastewater discharges, fertilizer runoff, animal metabolic excretions and breakdown of soil and other biological material. Large quantities of ammonia in natural waters generally indicate sewage contamination. All focus sites were rated as good for ammonia.

E. coli are found in the intestinal tract of warm-blooded animals. Most strains of *E. coli* are harmless; however, some strains can cause serious illness. Elevated *E. coli* values could stem from stormwater runoff washing waste into the stream or it could be indicative of an illegal or cross-connection between sanitary and storm sewer or from a leaky lateral or septic tank. While there is no standard for *E. coli*, median values are highest at urban locations. Values for *E. coli* are lower in the upper reaches of the Milwaukee and Menomonee Rivers compared to the values observed on the Kinnickinnic River sites and other urban locations on the Menomonee River. *E. coli* values are very low on the Milwaukee Harbor focus sites.

Fecal coliform bacteria are used as microbiological indicators of the safety of water for drinking or swimming. Water quality ratings were mixed, with three focus sites achieving good, five fair, and two poor. The presence of fecal coliforms indicates contamination from the intestinal tract of warm-blooded animals. The occurrence of bacterial, viral, protozoan, and possibly fungal species is indicated by the presence of the fecal coliform group of bacteria. Fecal coliform bacteria can enter the waterways through stormwater runoff (pet waste, etc.), combined sewer overflows, direct deposit (birds), illegal sanitary sewer connections, cross-connections, or leaky sanitary pipes.

Biochemical oxygen demand (BOD) is used to estimate the concentration of oxygen-demanding material in water. High levels of BOD can depress DO concentrations to levels harmful to aquatic organisms. Sources of BOD can be either carbonaceous or nitrogenous. While there is no standard in

place for BOD, values are highest at urban sites. Of the focus sites analyzed in this report, the sites further upstream generally have the lowest BOD values. Sites influenced by Lake Michigan water (RI-19) also have very low BOD values. Milwaukee Harbor sites are generally below the MDL for BOD. The highest BOD values within our sampling program are found on the Kinnickinnic River with many of these higher values occurring during the winter months as de-icing fluids enter the Kinnickinnic River through Wilson Park Creek.

Conclusion

The Freshwater Resources Monitoring Department collected over 63,000 data points in 2016 from 91 unique sites (Fig. 1) for over 40 parameters (Table 3). For the summary report each year, the Freshwater Resources Monitoring department focuses on different sites and/or parameters to analyze in further depth. This is intended to provide a snapshot of the overall water quality in the region; however, additional data and analysis can be provided by request for the sites and parameters that were not highlighted this year.

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