2017

MILWAUKEE RIVER BASIN REPORT CARD

MILWAUKEE RIVERKEEPER®

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Dear Friend of the River,

On behalf of Milwaukee Riverkeeper, we welcome you to our Eighth Annual Milwaukee River Basin Report Card. This year's Report Card summarizes the 2017 water quality of the Milwaukee River Basin, an 882.3 square mile area located in Southeastern Wisconsin, which contains approximately 500 miles of perennial streams, over 400 miles of intermittent streams, 35 miles of Lake Michigan shoreline, 57 named lakes, and over 1.3 million people.

In 2017, the Milwaukee River Basin received a grade of C- (71.40%), a notable improvement from last year's grade of D+ (68.10%). Nonetheless, the individual watershed and water quality parameter grades within the Milwaukee River Basin vary widely. In analyzing the data collected, our Report Card allows us to interpret and summarize the aquatic health of our Basin's three major rivers, and smaller subwatersheds.

Data obtained by our dedicated Milwaukee Riverkeeper volunteer water monitors, along with data from other major contributors like the Milwaukee Metropolitan Sewerage District (MMSD), Wisconsin Department of Natural Resources (WDNR), and Ozaukee County Parks and Planning Department, make this Report Card possible. This data includes standard water quality parameters such as dissolved oxygen, temperature, turbidity, pH, and macroinvertebrates (aquatic organisms), along with data on contaminants of concern and bacteria. By compiling and averaging the data, we were able to calculate and assign water quality grades to assess the relative health of the watersheds.

Our Report Card also highlights results and insights from other Milwaukee Riverkeeper initiatives such as freshwater mussel monitoring and macroinvertebrate monitoring. An article by UW-Milwaukee School of Freshwater Sciences Proffesor Dr. Ryan Newton entitled "Mircoorganisms and Rivers" is also included.

While reading our Report Card, keep in mind that annual snapshots of water quality data often paint a "depressing" picture of river health. Year after year, we observe the same pollutants exceeding water quality standards, and very few water quality grade improvements. The reality is, it took a long time to pollute our rivers, and it's going to take a long time to bring water quality grades from D's back to A's. Yet, the community is ready for this change and through joint, collaborative efforts throughout our watersheds, progress is being made. It is an exciting time for our community, and here at Milwaukee Riverkeeper, we are working tirelessly to achieve our goal of swimmable, fishable, drinkable water quality.

As always, Milwaukee Riverkeeper extends our sincerest thanks to our volunteer water monitors, our partners, and to all of our water advocates.

Sincerely,

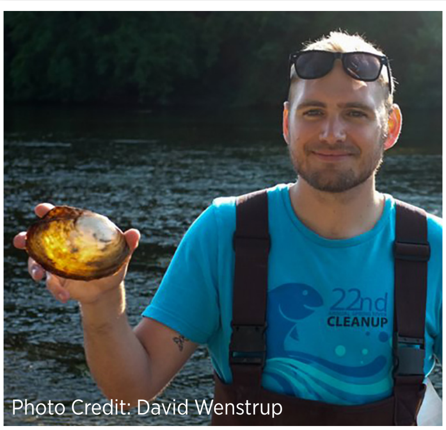

Photo Credit: David Wenstrup

Zac Driscoll
Zac Driscoll,
Freshwater Biologist

Cheryl Nenn,
Riverkeeper

Jacob Rogers
Jacob Rogers,
Water Quality Intern

THANK YOU TO OUR REPORT CARD SPONSORS FOR THEIR GENEROUS SUPPORT

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Written by: Ryan Newton, Ph.D., M.S.C.E.

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2017 MILWAUKEE RIVER BASIN GRADE

Milwaukee Riverkeeper's analysis of 2017 water quality data from the Milwaukee, Menomonee, and Kinnickinnic River Watersheds indicates an overall grade of C- (71.40%) for the Milwaukee River Basin. As with previous years, exceedances of water quality standards for phosphorus, specific conductivity, and bacteria remain a big concern throughout the entire Basin. Low grades for these parameters is likely the result of land use practices, failing infrastructure, and human activities that send pollutants to rivers and streams. Nonetheless, 2017 grades show improvement for many water quality parameters throughout each watershed and subwatershed of the Basin from 2016 to 2017.

The data for this Report Card was collected year-round and submitted to the WDNR Surface Water Integrated Monitoring System (SWIMS) database by Milwaukee Riverkeeper, Ozaukee County Department of Parks and Planning, Urban Ecology Center, and WDNR. From there, Milwaukee Riverkeeper retrieved the relevant water quality data from SWIMS, as well as data from MMSD. Water quality data for each parameter was analyzed and grades were given based on the percentage of data points that met our targets relating to aquatic ecosystem health. These grades are based on federal and state standards for water quality, as well as other available guidance (see pages 29 and 30). Grades are assigned on a typical percentage scale (see below). Overall watershed and subwatershed grades are computed by averaging their respective individual parameter grades. The overall Milwaukee River Basin grade is determined by averaging overall grades for the three major watersheds (Milwaukee, Menomonee, and Kinnickinnic).

It is important to note that issues such as legacy contamination, emerging pollutants, and stream conditions are not factored into our grading system. These factors are important and may pose challenges to meeting our water quality and habitat goals. For example, legacy pollutants such as polychlorinated biphenyls (PCBs), heavy metals, and petroleum products can also impair stream health, but monitoring for these contaminants is extremely expensive. Likewise, the geographic distribution of our sampling sites puts some limitations on the statistical strength of our comparisons between different areas of the Basin. This Report Card is a snapshot of water quality throughout the Milwaukee River Basin for 2017, and provides us with general information on overall stream health, challenges in meeting our water quality goals, and opportunities for implementing projects and changing policies. Long term trends are also important and touched on in several places throughout the Report Card.

A — All water quality indicators meet desired targets **90 - 100%** of the time. Streams or river segments have "good" water quality, which are capable of supporting fish and other aquatic life.

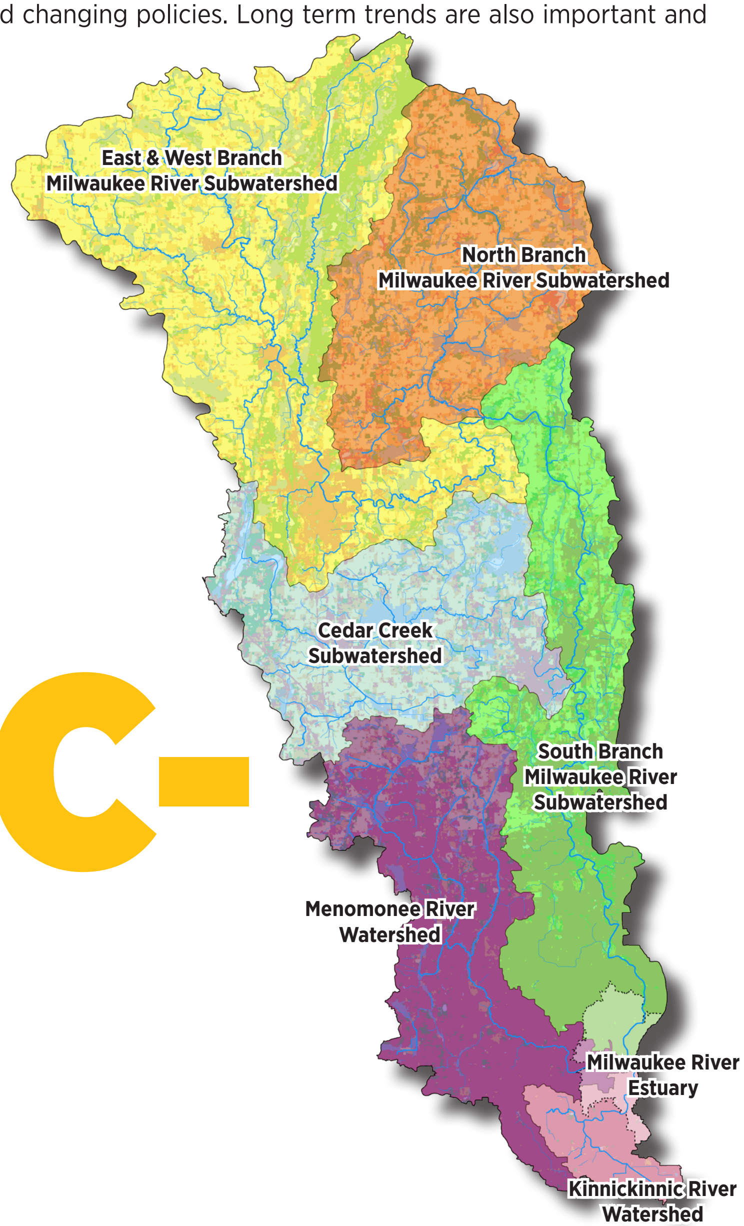
B — Most water quality indicators meet desired targets roughly **80 - 89%** of the time. Water quality of these streams and river segments tend to be good. Most areas are capable of supporting fish and other aquatic life.

C — There is a mix of healthy and unhealthy water quality indicators or indicators are only meeting water quality targets **70 - 79%** of the time. Water quality of these waters tends to be fair, and has fair conditions for fish and most aquatic life.

D — Few water quality indicators meet desired targets or only meet water quality targets **60 - 69%** of the time. Water quality and wildlife habitat of these waters tends to be poor.

F — Very few water quality indicators meet desired targets or meet water quality targets **below 60%** of the time. Water quality of these streams and river segments is very poor and most often leads to poor conditions for fish and aquatic life.

C-



WATER QUALITY MONITORING

Volunteers are essential to the success of Milwaukee Riverkeeper's work. Every month during the summer, our water quality monitors make their way to river stations throughout the Milwaukee River Basin. This amazing group of individuals dedicate their time and talent so we can gain a better understanding of the health of our rivers.

VOLUNTEER SPOTLIGHT

Paul Lindquist
3rd Year Volunteer

Why did you first become a monitor?

I enjoy interacting with nature. Being a Milwaukee Riverkeeper volunteer gives purpose to the interaction.

What monitoring programs have you participated in?

Water quality, sodium chloride, and emerging contaminant monitoring.

What is your favorite monitoring program that you have participated in?

The monthly river monitoring visits. Volunteers are able to see the seasonally changing waterway and understand the fragility of the ecosystem.

What is your favorite part of being a water quality monitor?

The sense of purpose and understanding what the Milwaukee River and its tributaries provide.

John McKay
3rd Year Volunteer

Sue McKay
3rd Year Volunteer

Why did you first become a monitor?

We live on the Milwaukee River. Monitoring is a way for us to help Milwaukee Riverkeeper work toward the goal of a healthier Milwaukee River Basin.

What monitoring programs have you participated in?

Water quality and sodium chloride monitoring.

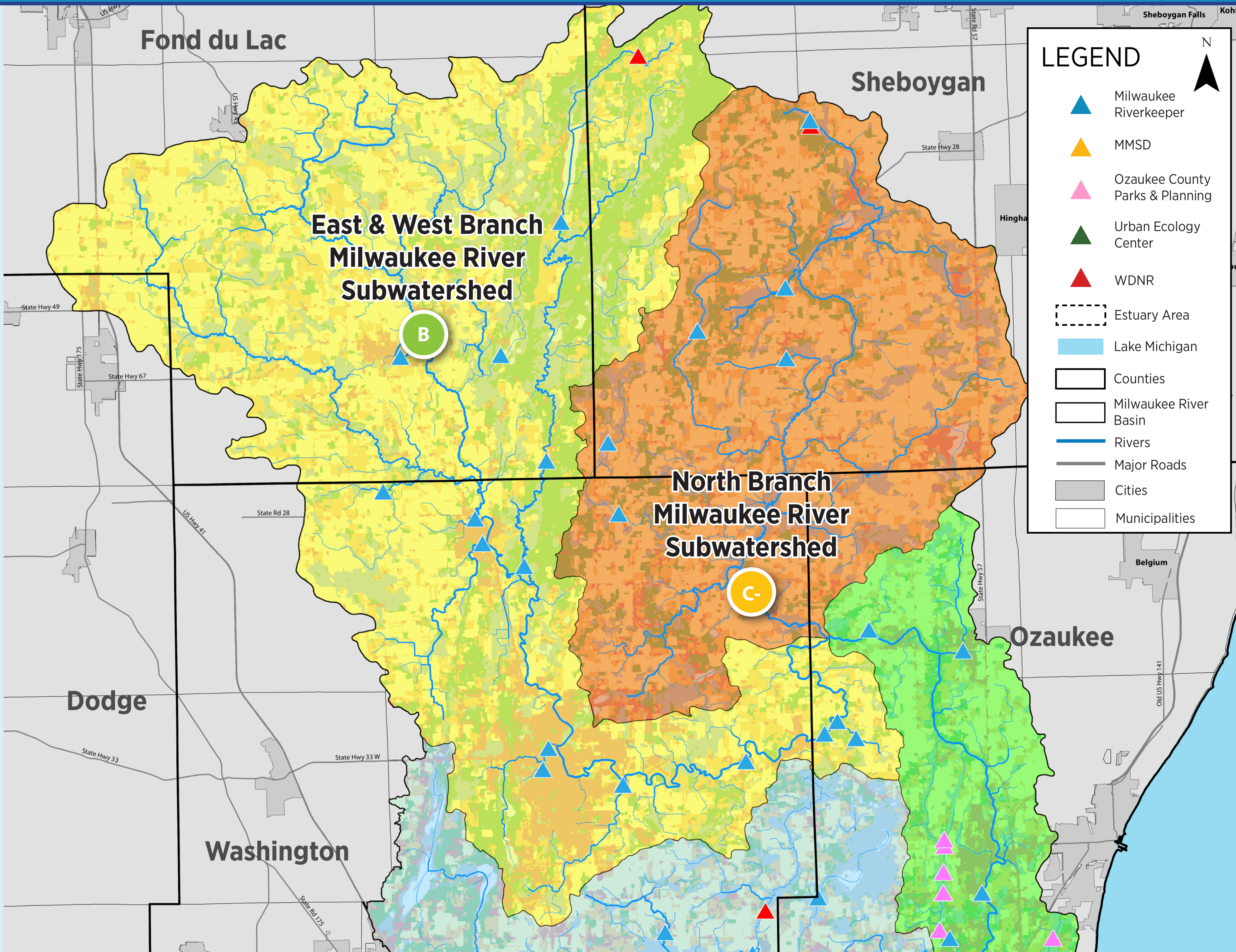
What is your favorite monitoring program that you have participated in?

We thought the winter chloride monitoring was very interesting. The correlation between the road salt and our meter readings was easy to understand. It made us really think about the use.

What is your favorite part of being a water quality monitor?

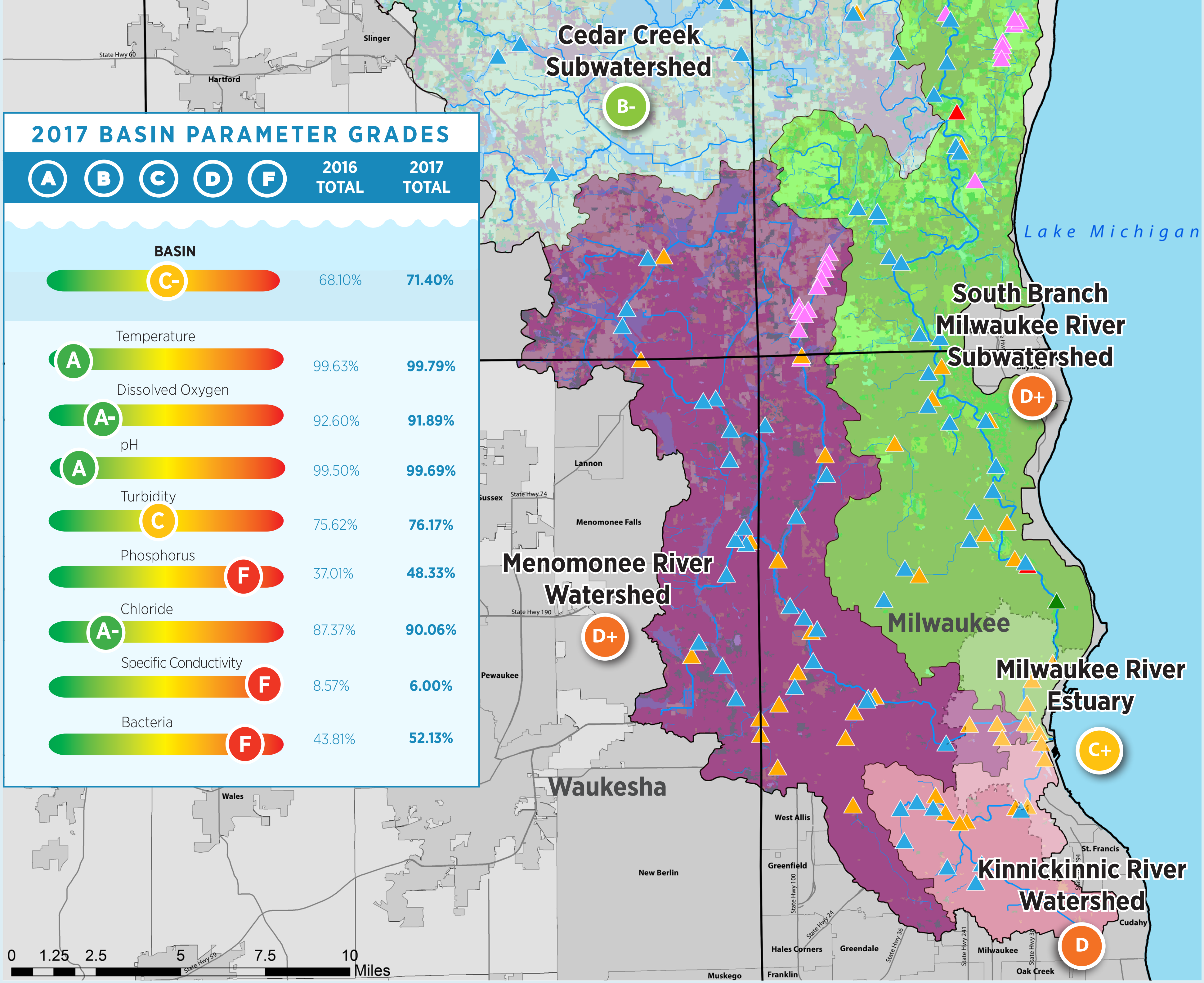
Besides doing something worthwhile together, we've enjoyed learning new things. In particular, Sue learned the importance of the macroinvertebrates and looks at them as more than just bugs in the water.

MILWAUKEE RIVER BASIN MAP

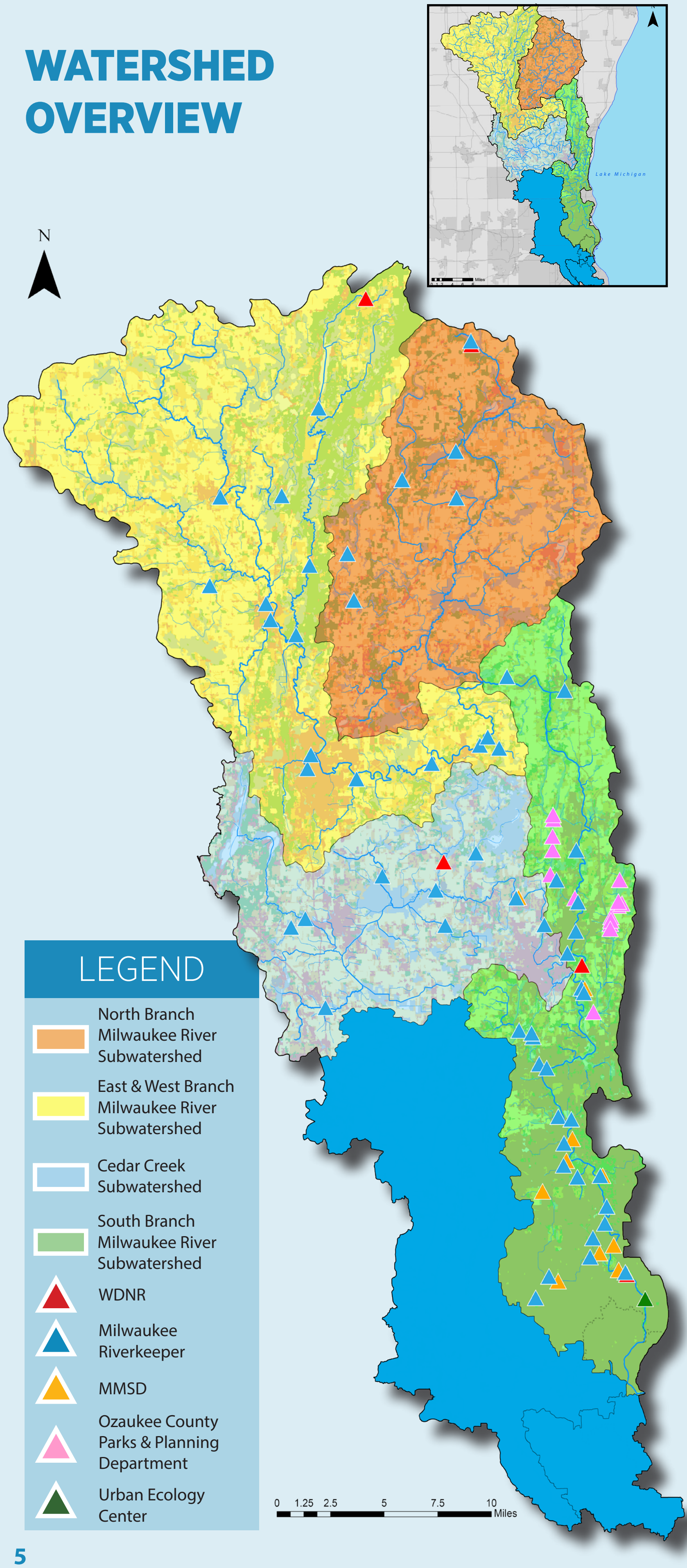


2017 BASIN PARAMETER GRADES

Parameter	Grade (A B C D F)	2016 TOTAL	2017 TOTAL
BASIN	C-	68.10%	71.40%
Temperature	A	99.63%	99.79%
Dissolved Oxygen	A-	92.60%	91.89%
pH	A	99.50%	99.69%
Turbidity	C	75.62%	76.17%
Phosphorus	F	37.01%	48.33%
Chloride	A-	87.37%	90.06%
Specific Conductivity	F	8.57%	6.00%
Bacteria	F	43.81%	52.13%



WATERSHED OVERVIEW



MILWAUKEE RIVER WATERSHED QUICK FACTS

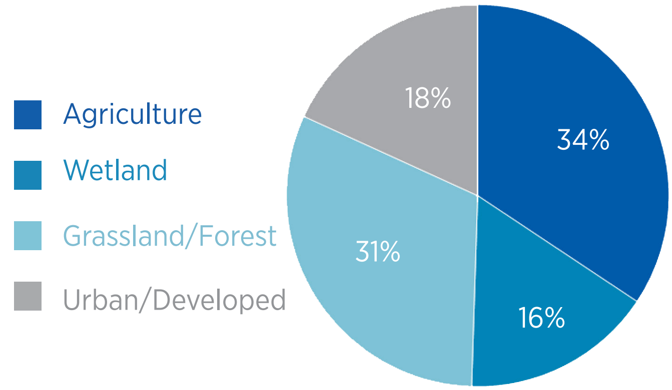
RIVER MILE FACTS

704 mi. total miles

18 mi. of trout streams

341 mi. of impaired waters

LAND USE BREAKDOWN



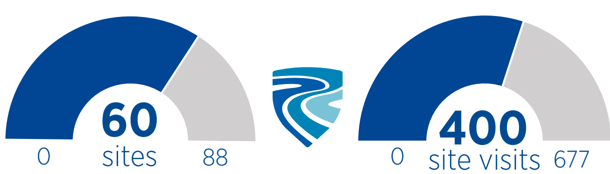
NOTE: 1% of land use is unaccounted for

2017 MONITORING FACTS

88 total sites

677 total site visits

Milwaukee Riverkeeper Data Contribution:



Other Data Contributors:

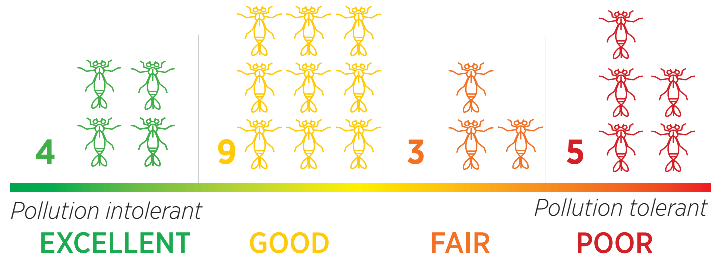
2017 DATA SUMMARY

Average Macroinvertebrate Biotic Index Score

2.33

The “Macroinvertebrate Biotic Index Score” measures the composition of stream invertebrates that are present. A high Biotic Index indicates a healthy stream. 98 samples were collected during the 2017 monitoring season.

Macroinvertebrate Types Observed Across all Surveys



In 2017, the Milwaukee River Watershed received a C- (71.36%) for overall water quality. Though the percentage of data meeting water quality standards for the Watershed declined from 2016, the decrease was insignificant (0.28%). In fact, all water quality parameter grades for the Milwaukee River Watershed varied less than 5% between 2016 and 2017, suggesting relatively steady water quality conditions.

The four major Subwatersheds that make up the Milwaukee River Watershed include the North Branch, the East and West Branch, and South Branch of the Milwaukee River, as well as Cedar Creek. Large variation in water quality exists between these Subwatersheds as revealed by their respective water quality grades. The East and West Branch received the highest overall water quality grade of B (84.40%), the South Branch had the lowest scoring a D (67.85%), and Cedar Creek and the North Branch fell in between with grades of B- (80.96%) and C- (72.76%) respectively.

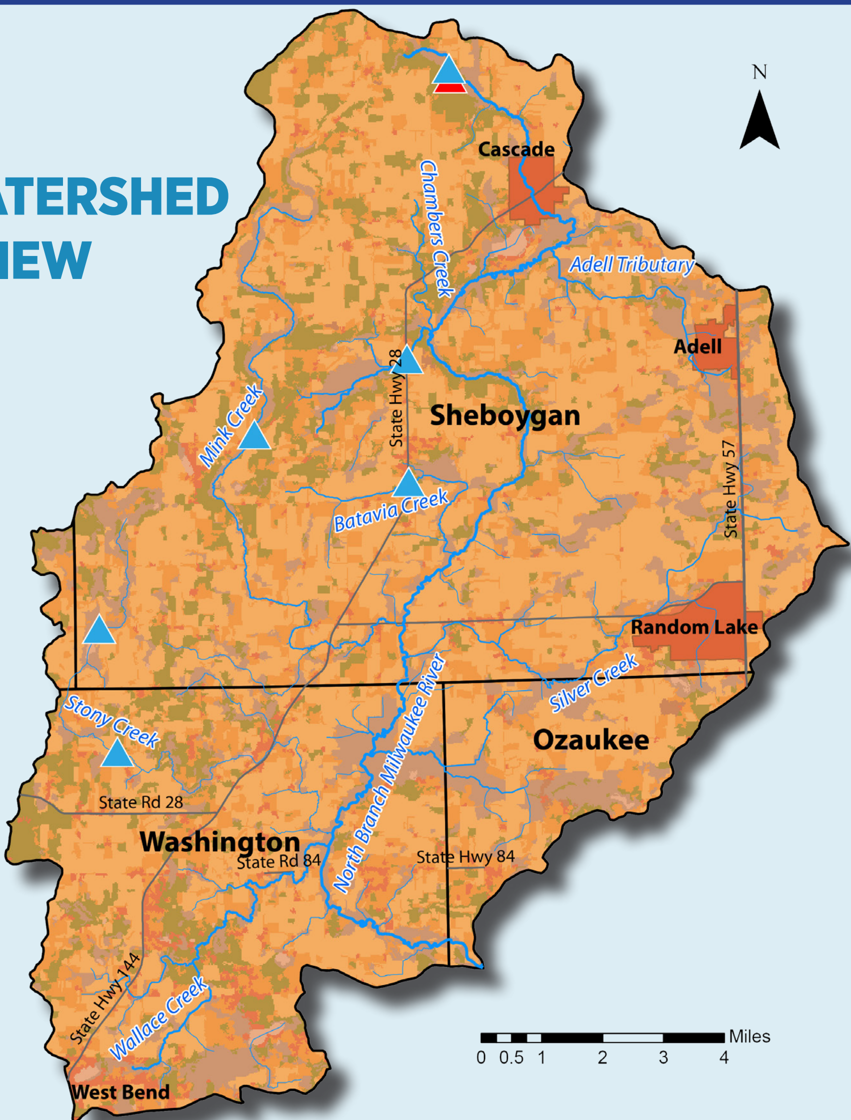
Though many factors likely play a role in the varied water quality grades throughout the Milwaukee River Watershed, the different land uses observed in each Subwatershed is the primary factor. The southern reaches of the Watershed fall within the City of Milwaukee, where a relatively high percentage of urban land use exists. Urbanization increases the amount of impervious surfaces within a watershed, reduces riparian buffer zones, and introduces human-caused pollution sources; all of which results in increased stormwater runoff and worsening water quality conditions. Conversely, the three remaining Subwatersheds have a relatively mixed land use with agricultural fields and natural areas more commonly present. While, agriculture presents its own challenges to achieving swimmable and fishable waterways, the presence of natural features in these Subwatersheds (e.g., Jackson Marsh and the Kettle Moraine North State Forest) are likely helping to balance out these effects to some extent.

2017 WATERSHED PARAMETER GRADES

	Grade (A B C D F)	2016 TOTAL	2017 TOTAL
WATERSHED	C-	71.65%	**71.36%**
Temperature	A	99.15%	**99.51%**
Dissolved Oxygen	B+	93.21%	**89.74%**
pH	A	99.32%	**99.80%**
Turbidity	C	77.14%	**74.29%**
Phosphorus	F	39.35%	**38.52%**
Chloride	A	96.10%	**97.46%**
Specific Conductivity	F	8.06%	**6.67%**
Bacteria	F	55.27%	**53.37%**

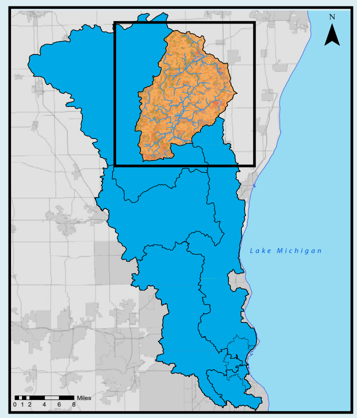
Finally, despite varied land use between the Subwatersheds, some trends persist. Most notably is the failing grade for total phosphorus observed throughout the Watershed. In rural areas, total phosphorus pollution is typically assumed to be agriculturally derived; making its way into waterways via runoff from farm fields and livestock operations. In urban areas, total phosphorus pollution is more commonly the result of permitted wastewater and stormwater discharges. Therefore, multiple sources of total phosphorus lead to water quality problems. Reducing total phosphorus to meet water quality standards will require investment, innovation and collaboration between stakeholders throughout the Milwaukee River Watershed and Basin.

SUBWATERSHED OVERVIEW



LEGEND

- North Branch Milwaukee River Subwatershed
- Cities
- Counties
- Rivers
- Major Roads
- WDNR
- Milwaukee Riverkeeper



NORTH BRANCH QUICK FACTS

RIVER MILE FACTS

147 mi.
total miles

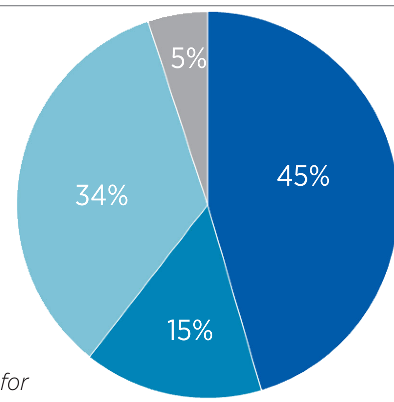
7 mi.
of trout streams

87 mi.
of impaired waters

LAND USE BREAKDOWN

- Agriculture
- Wetland
- Grassland/Forest
- Urban/Developed

NOTE: 1% of land use is unaccounted for

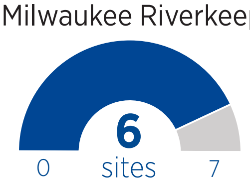


2017 MONITORING FACTS

7
total sites

60
total site visits

Milwaukee Riverkeeper Data Contribution:

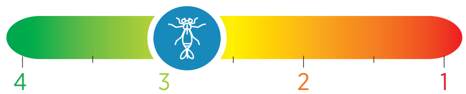


Other Data Contributors:

2017 DATA SUMMARY

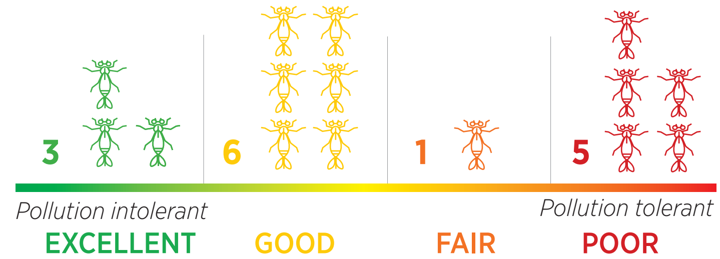
Average Macroinvertebrate Biotic Index Score

2.75



The "Macroinvertebrate Biotic Index Score" measures the composition of stream invertebrates that are present. A high Biotic Index indicates a healthy stream. 7 samples were collected during the 2017 monitoring season.

Macroinvertebrate Types Observed Across all Surveys



In 2017, the North Branch of the Milwaukee River Subwatershed received a C- (72.76%) for overall water quality. This grade is a moderate improvement from last year when the Subwatershed received a D (65.85%). New sites in 2017 included one site on the Class I Trout Stream, Nichols Creek, and two sites on Stoney Creek, a warmwater stream. In general, these sites tended to have better water quality than other stations previously monitored in 2016.

The most notable water quality parameter for the North Branch was dissolved oxygen (DO), which received a B- (81.63%). This was the lowest grade observed for this water quality parameter in the entire Milwaukee River Basin. Volunteers monitoring the North Branch noted stagnant water conditions at their sites during portions of the year. Since water movement can help DO diffuse into rivers, stagnant water can be linked to low DO levels.

Likewise, the high percentage of agricultural land use in this Subwatershed could also be contributing to low oxygen conditions. During rain events, fertilizers runoff from fields and make their way into our waterways. Once there, the nutrients present in these fertilizers promote plant and algal growth. These plants and algae will eventually die off, and are subsequently broken down by bacteria. The decomposition process requires large amounts of DO, resulting in low oxygen conditions.

A lower than average DO is not a new problem for the North Branch of the Milwaukee River, as we have observed a similar trend for the last 3 years. That being said, a B- for this parameter is a substantial improvement compared to last year, when DO received a D- (60.87%). An important factor to keep in mind when interpreting this grade improvement is that additional data points from the new 2017 monitoring sites received higher DO grades. Two of the three new sites maintained DO levels well above the water quality standard for the entire monitoring season. These results are promising as it suggests that DO is not bad for the entire Subwatershed, but could instead be limited to more ephemeral creeks, or those more impacted by agricultural runoff. Increasing the number of monitoring sites in this Subwatershed would help us better understand how widespread the low DO problem is in North Branch of the Milwaukee River. As such, going forward, we will be adding monitoring sites and will **need more volunteers in this area.**

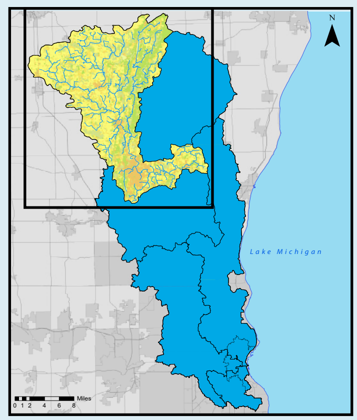
2017 SUBWATERSHED PARAMETER GRADES

	Grade (A B C D F)	2016 TOTAL	2017 TOTAL
SUBWATERSHED	C-	65.85%	**72.76%**
Temperature	A	100.00%	**100.00%**
Dissolved Oxygen	B-	60.87%	**81.63%**
pH	A	100.00%	**100.00%**
Turbidity	A	75.00%	**95.12%**
Phosphorus	F	38.10%	**36.17%**
Chloride		N/A	**N/A**
Specific Conductivity	F	0.00%	**3.70%**
Bacteria		N/A	**N/A**

EAST & WEST BRANCH MILWAUKEE RIVER SUBWATERSHED

B

SUBWATERSHED OVERVIEW



EAST & WEST BRANCH QUICK FACTS

RIVER MILE FACTS

233 mi.
total miles

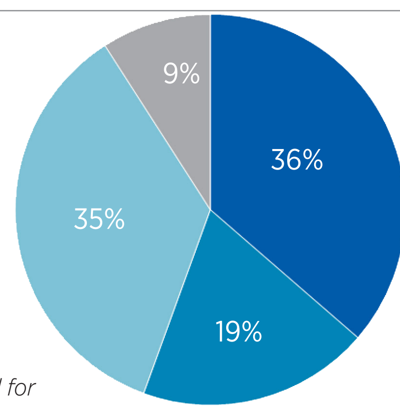
11 mi.
of trout streams

100 mi.
of impaired waters

LAND USE BREAKDOWN

- Agriculture
- Wetland
- Grassland/Forest
- Urban/Developed

NOTE: 1% of land use is unaccounted for

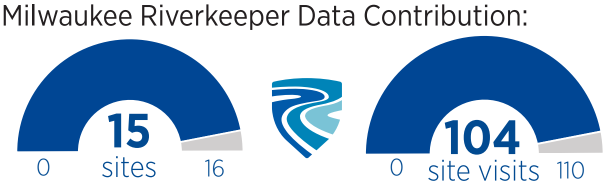


2017 MONITORING FACTS

16
total sites

110
total site visits

Milwaukee Riverkeeper Data Contribution:



Other Data Contributors:

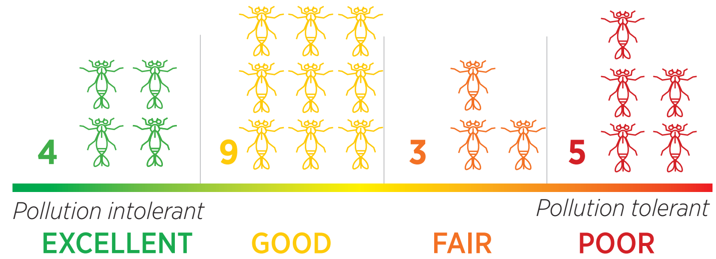
2017 DATA SUMMARY

Average Macroinvertebrate Biotic Index Score

2.36

The "Macroinvertebrate Biotic Index Score" measures the composition of stream invertebrates that are present. A high Biotic Index indicates a healthy stream. 28 samples were collected during the 2017 monitoring season.

Macroinvertebrate Types Observed Across all Surveys



In 2017, the East and West Branch of the Milwaukee River Subwatershed received a B (84.40%) for overall water quality. Though a slight departure from last year when the Subwatershed received a B+ (86.70%), this grade is the highest within the entire Basin for the second consecutive year.

The monitoring completed in 2017 likely depicts a more complete picture of water quality within this Subwatershed compared to previous years, because the number of data points in our analysis increased by over 80% from 2016 to 2017. The substantial increase in the number of additional data points between years is due to two factors. First, in 2017 seven new sites were added to our monitoring effort within this Subwatershed. These sites were added to help fill a water quality data gap that exists in the northern half of the Milwaukee River Basin. Second, additional data was collected at two of our existing sites for a special bacteria monitoring project completed by Milwaukee Riverkeeper.

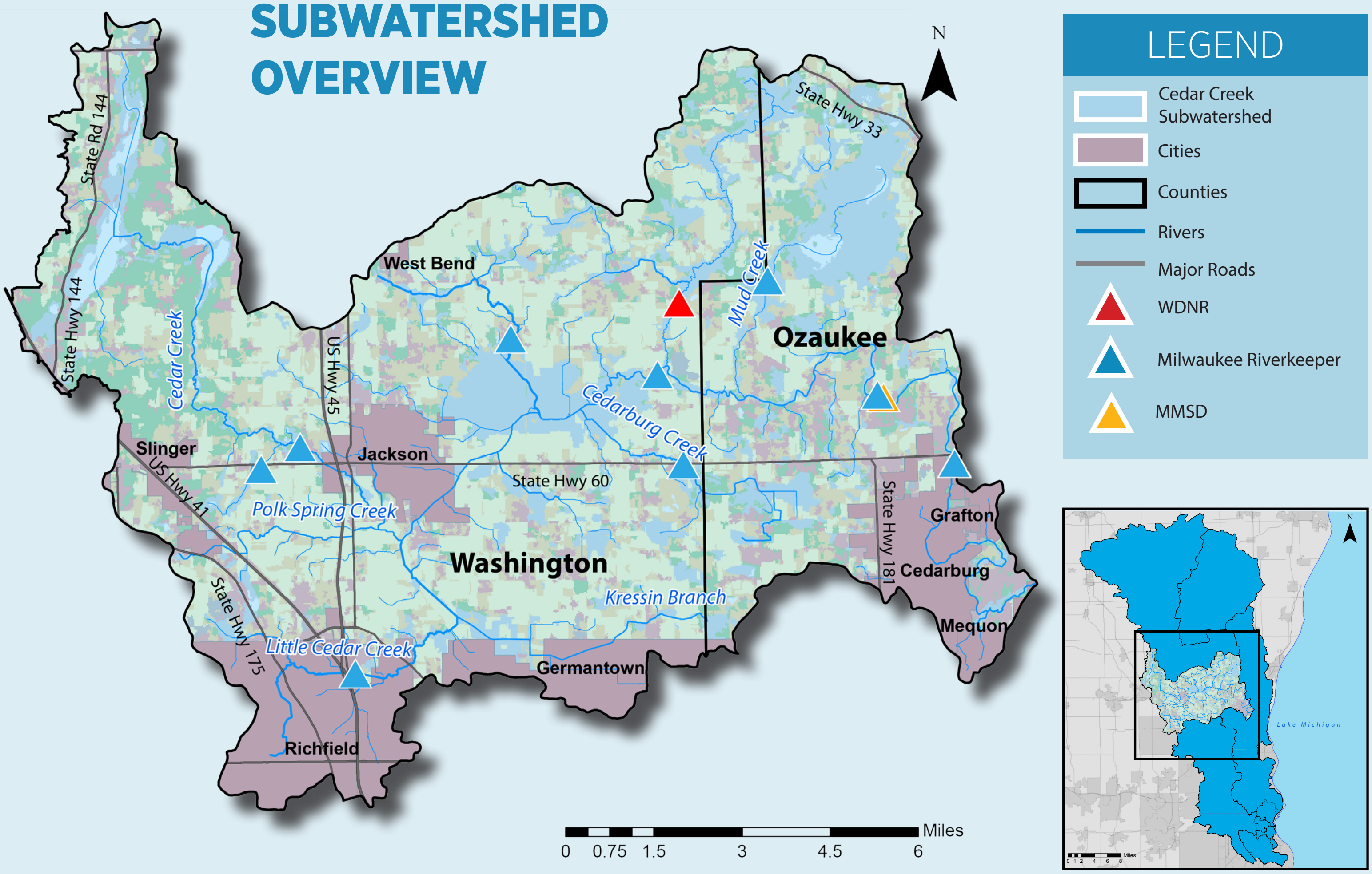
The worst water quality parameters in our analysis for the East and West Branch were total phosphorus and specific conductivity, both of which received failing grades with as little as 52.83% and 17.24% of data meeting standards or guidelines for each parameter, respectively. These parameters negatively impact river systems. For example, excess levels of phosphorus proliferate the growth of nuisance plants and algae, which negatively impacts natural stream processes, as well as other water quality parameters like dissolved oxygen. Likewise, though not inherently harmful, high levels of specific conductivity indicate that a water body is polluted with other chemicals. This may include compounds like ammonia or chloride which are toxic to fish and wildlife at high concentrations.

2017 SUBWATERSHED PARAMETER GRADES

Parameter	Grade (A B C D F)	2016 TOTAL	2017 TOTAL
SUBWATERSHED	B	86.70%	**84.40%**
Temperature	A	91.11%	**96.97%**
Dissolved Oxygen	A	97.83%	**96.81%**
pH	A	95.35%	**100.00%**
Turbidity	B+	97.50%	**87.64%**
Phosphorus	F	59.52%	**52.83%**
Chloride		N/A	**N/A**
Specific Conductivity	F	64.71%	**17.24%**
Bacteria		N/A	**N/A**

Furthermore, despite urban land use making up only 9% of the East and West Branch Subwatershed, failing grades are still observed for parameters of concern. This trend clearly demonstrates that urbanization and urban land use are not always the cause of poor water quality conditions. In the case of the East and West Branch, the problems with specific conductivity and total phosphorus are instead likely caused by the large percentage of the Subwatershed that is dedicated to agriculture. Runoff from farm fields and livestock operations act as major inputs of pollutants to our rivers in rural areas. A continued effort to work with farmers to employ best management practices is essential to limiting agricultural runoff and improving water quality in the East and West Branch of the Milwaukee River Subwatershed.

SUBWATERSHED OVERVIEW



CEDAR CREEK SUBWATERSHED QUICK FACTS

RIVER MILE FACTS

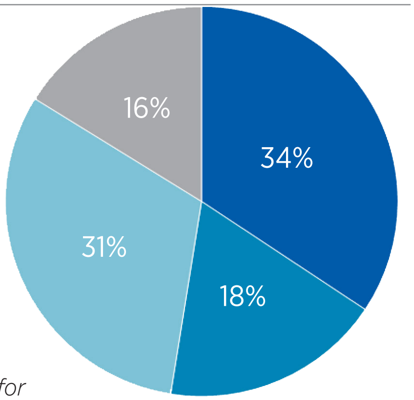
92 mi.
total miles

0 mi.
of trout streams

41 mi.
of impaired waters

LAND USE BREAKDOWN

- Agriculture
- Wetland
- Grassland/Forest
- Urban/Developed



NOTE: 1% of land use is unaccounted for

2017 MONITORING FACTS

11
total sites

82
total site visits

Milwaukee Riverkeeper Data Contribution:

Other Data Contributors:

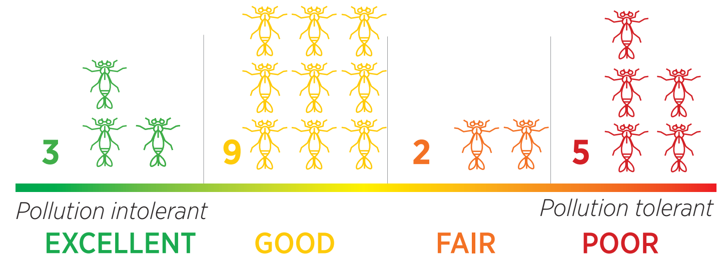
2017 DATA SUMMARY

Average Macroinvertebrate Biotic Index Score

2.18

“The “Macroinvertebrate Biotic Index Score” measures the composition of stream invertebrates that are present. A high Biotic Index indicates a healthy stream. 18 samples were collected during the 2017 monitoring season.

Macroinvertebrate Types Observed Across all Surveys



In 2017, the Cedar Creek Subwatershed received a B- (80.96%) for overall water quality. This grade represents a substantial improvement from last year when the Subwatershed received a D (67.18%). We greatly expanded our monitoring efforts within Cedar Creek from 2016-2017. Our volunteers collected 52% more data in 2017 compared to 2016. Our expanded 2017 analysis provides a better picture of overall water quality within the Subwatershed than previous years. That being said, other factors like weather patterns and changes to land management may have also influenced differences in water quality within Cedar Creek between years.

Turbidity and bacteria data influenced this grade improvement the most. The percentage of turbidity samples meeting the water quality standard increased over 10%, constituting a full letter grade improvement. The bacteria grade improved even more significantly from an F (50.00%) in 2016 to a B- (81.25%) in 2017. However, while this result may be considered a substantial improvement, it is important to acknowledge that the bacteria data analyzed for Cedar Creek came from a single station monitored by MMSD. Higher variability can be expected when the amount of available data is small. Increased monitoring for bacteria is neccessary to better understand this pollutant within the Subwatershed.

Similar to the North Branch of the Milwaukee River Subwatershed, Cedar Creek struggled with total phosphorus and specific conductivity issues. In fact, both of these water quality parameters received failing grades with as little as 37.50% and 0% of data points meeting recommended standards, respectively. In particular, the grade for specific conductivity was the lowest observed for this parameter within the entire Milwaukee River Basin.

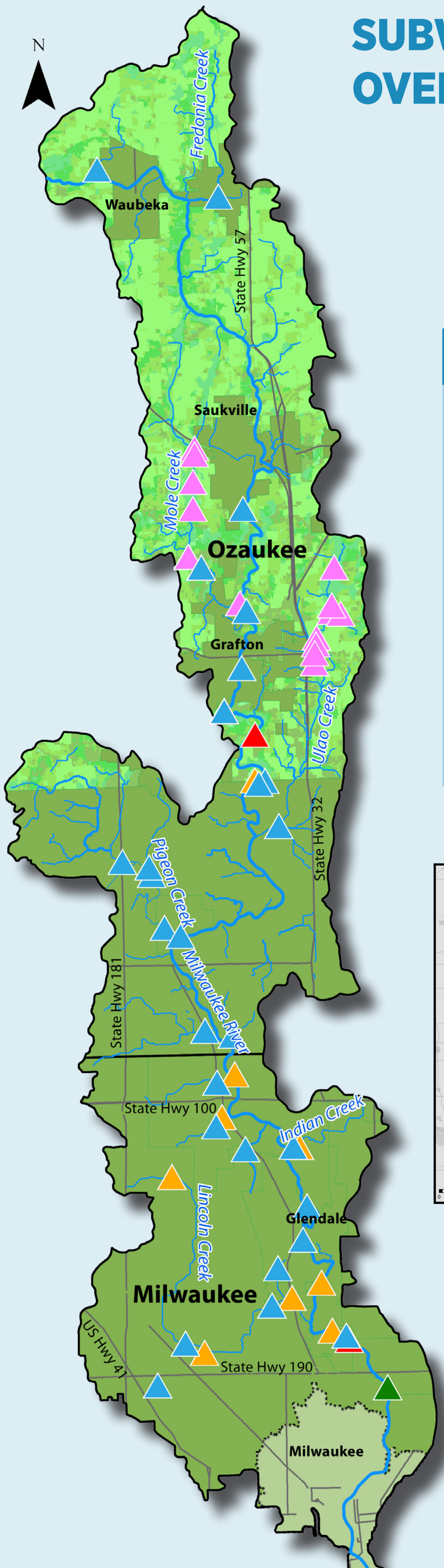
2017 SUBWATERSHED PARAMETER GRADES

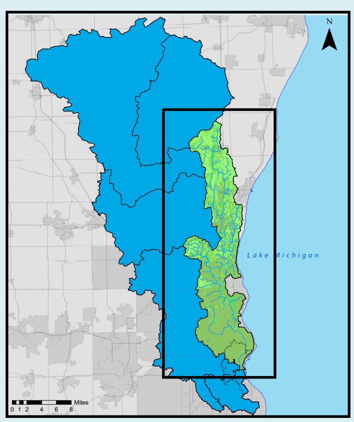
A B C D F	2016 TOTAL	2017 TOTAL
SUBWATERSHED B-	67.18%	**80.96%**
Temperature A	100.00%	**100.00%**
Dissolved Oxygen A-	100.00%	**91.14%**
pH A	100.00%	**100.00%**
Turbidity A-	81.58%	**92.75%**
Phosphorus F	39.02%	**37.50%**
Chloride A	100.00%	**100.00%**
Specific Conductivity F	2.56%	**0.00%**
Bacteria B-	50.00%	**81.25%**

This Subwatershed’s land use is nearly equally balanced between developed and natural areas. Regarding anthropogenic practices, agriculture is likely the main driver of water quality changes from year to year. Like the East and West Branch Subwatershed, phosphorus from fertilizers enter aquatic systems via runoff, and influence natural ecological cycles, as well as impact other water quality parameters. Excess phosphorus in ionic form increases the amount of charged particles within waterways, which increases conductivity to levels that adversely affect aquatic life. In addition, other ions like nitrates and potassium that are found in fertilizer, further increase the specific conductivity levels in impacted waterways. Ongoing efforts to work with farmers to find solutions to curb agricultural runoff would further benefit water quality in the Cedar Creek Subwatershed.

SOUTH BRANCH MILWAUKEE RIVER SUBWATERSHED D+

SUBWATERSHED OVERVIEW





SOUTH BRANCH QUICK FACTS

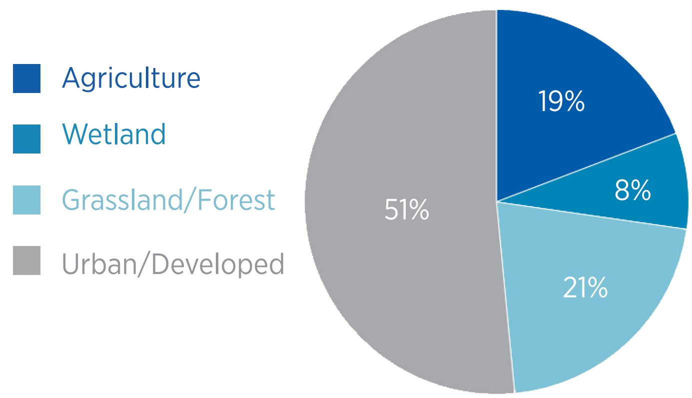
RIVER MILE FACTS

232 mi. total miles

0 mi. of trout streams

113 mi. of impaired waters

LAND USE BREAKDOWN



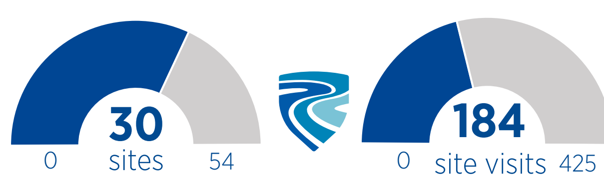
NOTE: 1% of land use is unaccounted for

2017 MONITORING FACTS

54 total sites

425 total site visits

Milwaukee Riverkeeper Data Contribution:

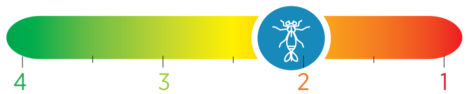


Other Data Contributors:

2017 DATA SUMMARY

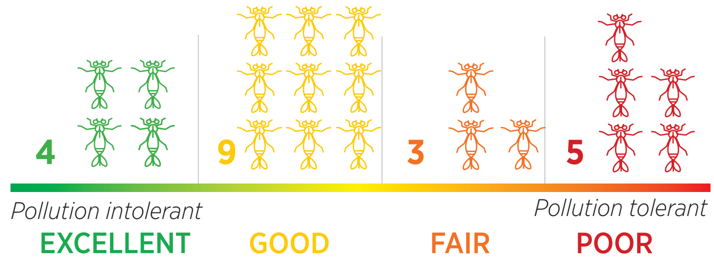
Average Macroinvertebrate Biotic Index Score

2.29



The "Macroinvertebrate Biotic Index Score" measures the composition of stream invertebrates that are present. A high Biotic Index indicates a healthy stream. 45 samples were collected during the 2017 monitoring season.

Macroinvertebrate Types Observed Across all Surveys



In 2017, the South Branch of the Milwaukee River Subwatershed received a D+ (67.85%) for overall water quality. This grade was a slight drop from last year when the Subwatershed also received a D+ (69.30%). Water quality tests from 2017 had a slightly smaller percentage of data points meeting water quality goals (1.45%). We observed the least variation in grades for the South Branch between years as compared to all other Subwatersheds analyzed. With the exception of turbidity, every parameter analyzed in 2017 remained within 5% of its respective grade in 2016, suggesting relatively steady water quality conditions within this Subwatershed. **As for individual parameters, aside from Basin-wide reoccurring water quality issues such as high phosphorus, specific conductivity, and bacteria, another bad water quality parameter for the South Branch was turbidity, which received a D (65.10%).** This was the lowest grade observed for turbidity throughout the Basin, and was over 10% lower than the Milwaukee River Basin average. Furthermore, the grade for turbidity in this Subwatershed dropped by 10% between 2016 and 2017. Though it's not clear why the grade dropped between years, the bad grade observed for turbidity is most likely related to land use and human activity within the Subwatershed coupled with increased precipitation.

2017 SUBWATERSHED PARAMETER GRADES

Parameter	Grade (A B C D F)	2016 TOTAL	2017 TOTAL
SUBWATERSHED	D+	69.30%	**67.85%**
Temperature	A	100.00%	**100.00%**
Dissolved Oxygen	B+	91.84%	**88.78%**
pH	A	99.60%	**99.74%**
Turbidity	D	75.09%	**65.10%**
Phosphorus	F	34.94%	**36.76%**
Chloride	A	93.94%	**97.24%**
Specific Conductivity	F	3.18%	**6.54%**
Bacteria	F	50.94%	**50.34%**

Over half of the area within the South Branch Subwatershed is made up of urban land use. Urbanization can increase erosion, siltation, and runoff, which in turn negatively affects water clarity. For example, as the amount of urban land use increases within a watershed, so does the area of impervious or hard surfaces. During precipitation events, impervious surfaces limit the amount of water that infiltrates into the ground, therefore increasing runoff. As precipitation runs along the land surface, it transports soil particles and other pollutants to the rivers, in turn increasing turbidity. In addition, problems with turbidity are further exacerbated when development begins to encroach on rivers. For instance, streamside vegetation shields riverbanks, slowing the flow of runoff from precipitation events, and reducing the magnitude of erosion that sends soil into streams. Therefore, when stream side vegetation is removed, erosion is intensified and turbidity increases within river systems. In the case of the South Branch Subwatershed, nearly 25% of the land in the riparian zone is either urban or developed, which is likely further increasing turbidity within the Subwatershed. Increased levels of turbidity within rivers and streams negatively impacts biota. Particles that settle out of the water column smother fish eggs and reduce available habitat for mussels and macroinvertebrates. Continued efforts to protect and stabilize stream banks and reduce runoff from precipitation events are essential to improving turbidity within our rivers.

We hope you enjoy this edition of our Annual River Report Card. Our work would not be possible without the support of people like you. Milwaukee Riverkeeper works to protect, improve and advocate for water quality, riparian wildlife habitat, and sound land management in the Milwaukee, Menomonee, and Kinnickinnic River Watersheds.

> We envision a future in which people from all walks of life can enjoy the healthy waterways of the Milwaukee River Basin.

Milwaukee Riverkeeper serves as a voice for the Milwaukee, Menomonee, and Kinnickinnic Rivers and works tirelessly for swimmable, fishable, drinkable waters. Our core programming involves water quality monitoring and advocating on behalf of the rivers.

We also coordinate hands-on river restoration projects and organize thousands of volunteers each year in river cleanups. We connect people to water through river-focused events and educate our community about water quality and river health.

> Help achieve swimmable, fishable, drinkable rivers.

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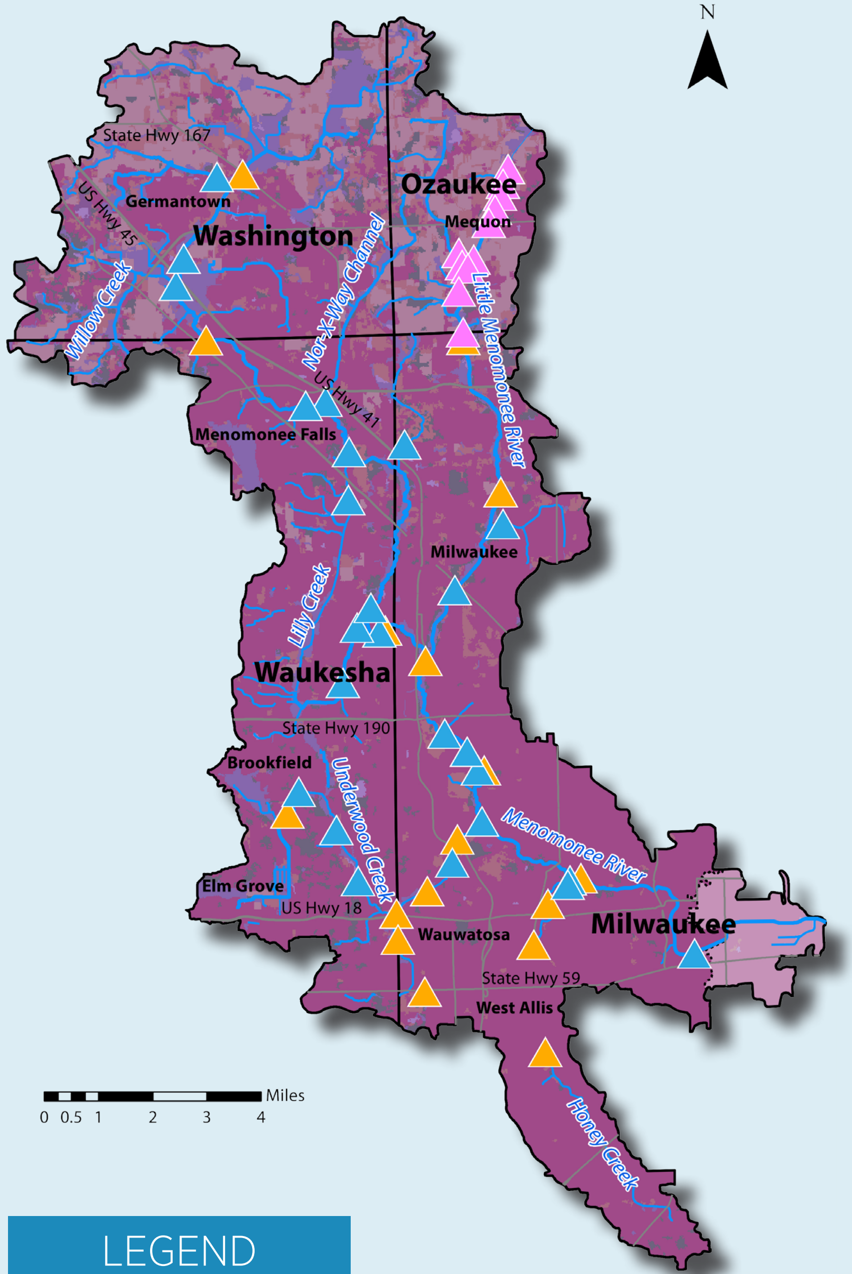
Milwaukee Riverkeeper is a licensed member of the Waterkeeper Alliance, an international coalition dedicated to clean water and healthy communities.


PROTECT
RESTORE
CONNECT
ADVOCATE

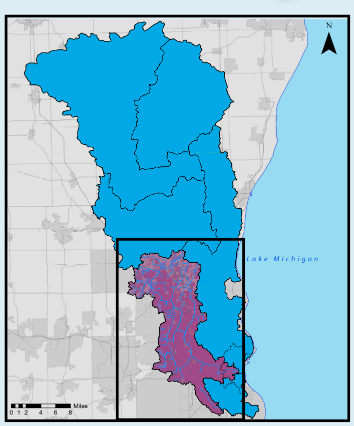
MENOMONEE RIVER WATERSHED

WATERSHED OVERVIEW



LEGEND

- Menomonee River Watershed
- Milwaukee River Estuary
- Cities
- Counties
- Rivers
- Major Roads
- Milwaukee Riverkeeper
- MMSD
- Ozaukee County Parks & Planning Department



MENOMONEE RIVER WATERSHED QUICK FACTS

RIVER MILE FACTS

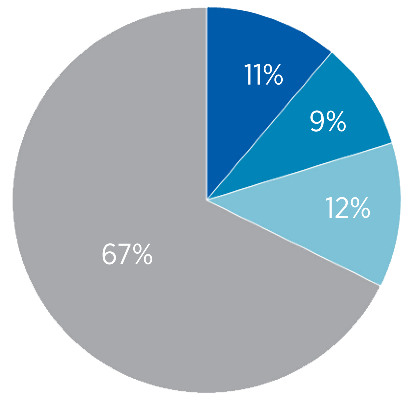
134 mi.
total miles

0 mi.
of trout streams

71 mi.
of impaired waters

LAND USE BREAKDOWN

- Agriculture
- Wetland
- Grassland/Forest
- Urban/Developed



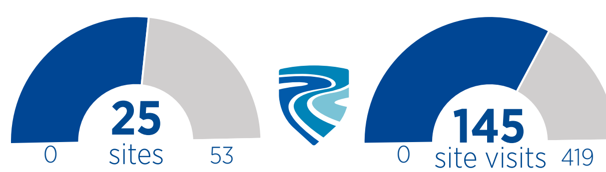
NOTE: 1% of land use is unaccounted for

2017 MONITORING FACTS

53 total sites

419 total site visits

Milwaukee Riverkeeper Data Contribution:



Other Data Contributors:

MMSD PARTNERS FOR A CLEANER ENVIRONMENT

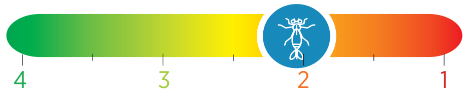
OZAUKEE COUNTY

WISCONSIN DEPT. OF NATURAL RESOURCES

2017 DATA SUMMARY

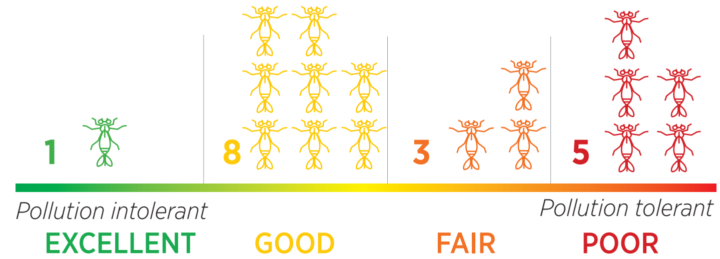
Average Macroinvertebrate Biotic Index Score

2.16



The "Macroinvertebrate Biotic Index Score" measures the composition of stream invertebrates that are present. A high Biotic Index indicates a healthy stream. 20 samples were collected during the 2017 monitoring season.

Macroinvertebrate Types Observed Across all Surveys



In 2017, the Menomonee River Watershed received a D+ (68.78%) for overall water quality. This is a slight improvement over 2016 when the Watershed received a D (64.02%). The primary parameters influencing the improved Watershed grade were total phosphorus and bacteria, which improved by 12.68% and 13.69%, respectively. Likewise, aside from specific conductivity, minor improvements (<5%) were also observed in all other parameters analyzed, suggesting a positive trend in overall water quality since 2016.

Despite the improvements, the Menomonee River Watershed still struggles to meet water quality standards for several parameters. For example, the Menomonee River received failing grades for total phosphorus, specific conductivity, and bacteria in 2017. The Watershed's bacteria grade is especially notable as it received one of the lowest observed grades within our Report Card. These are not new problems. With the exception of total phosphorus in 2012, all three aforementioned parameters in the Menomonee River Watershed have received failing grades within our Report Cards over the past six years.

In addition to the previously mentioned parameters, turbidity also received a relatively low grade (71.32%) compared to the other Watersheds and Subwatersheds analyzed. For example, the turbidity grade for the Menomonee River Watershed was nearly 25% lower than what we observed for the North Branch of the Milwaukee River Subwatershed (95.12%). The only region that scored lower in 2017 was the South Branch of the Milwaukee River Subwatershed. Interestingly, both the South Branch and the Menomonee River share similar land use composition with urban land use in their southern reaches and agricultural land use in their northern reaches. Other factors such as urban/suburban development and conversion of farm fields and natural areas to impervious surfaces is likely also contributing to more pollution in both of these Watersheds.

2017 WATERSHED PARAMETER GRADES

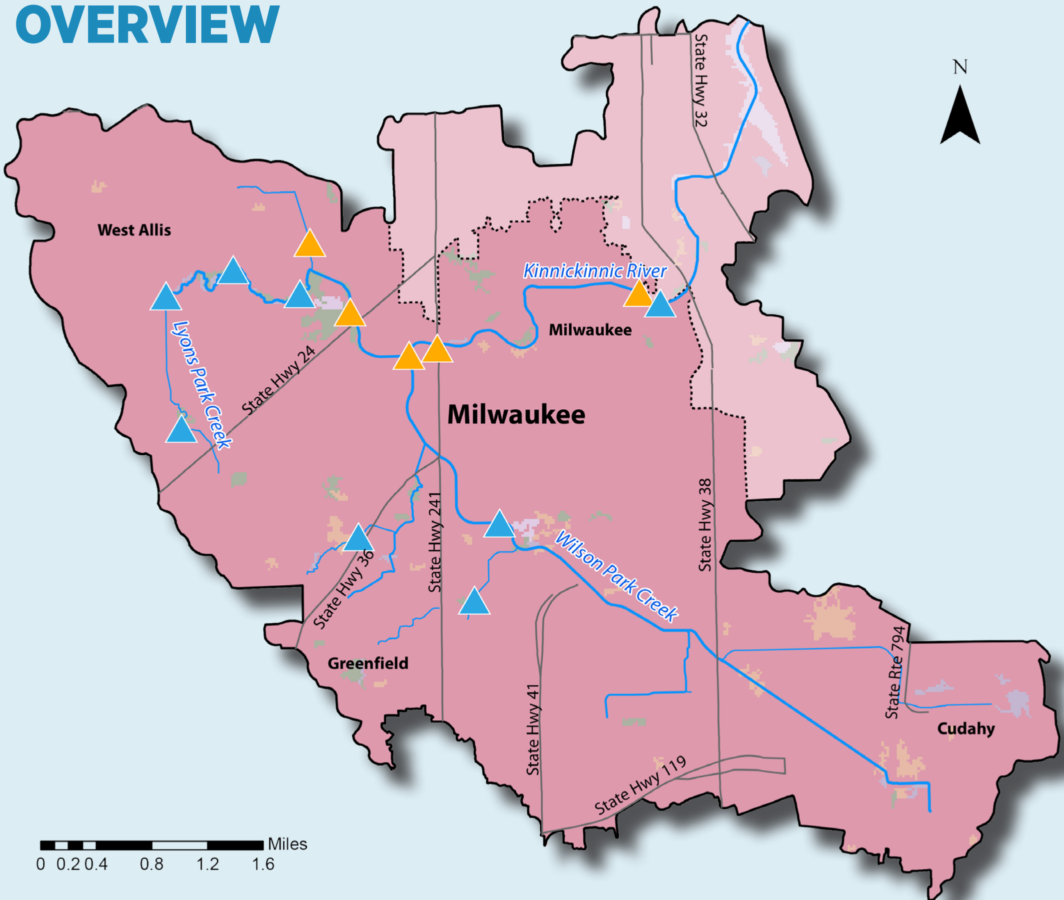
A B C D F	2016 TOTAL	2017 TOTAL
WATERSHED: D+	64.02%	**68.78%**
Temperature: A	100.00%	**100.00%**
Dissolved Oxygen: A	92.18%	**94.03%**
pH: A	99.37%	**99.74%**
Turbidity: C-	71.27%	**71.32%**
Phosphorus: F	35.29%	**47.98%**
Chloride: A-	88.72%	**91.10%**
Specific Conductivity: F	3.65%	**1.88%**
Bacteria: F	32.17%	**45.86%**

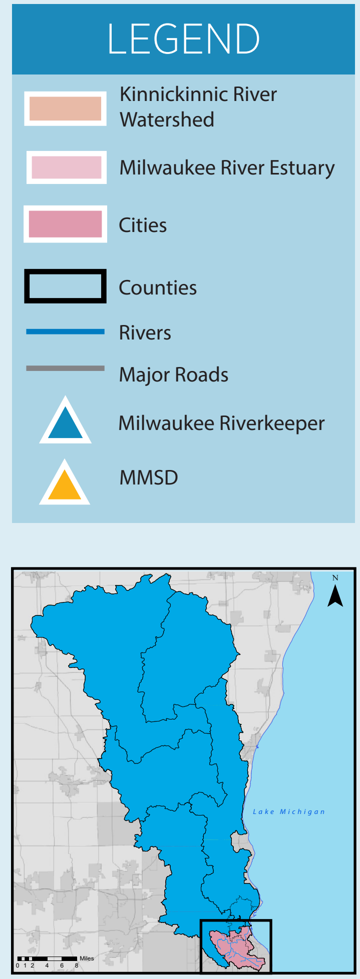
Although the low grades observed are of concern, positive action is being made to help the Menomonee River Watershed, and the entire Milwaukee River Basin, meet water quality standards. In 2017, the WDNR and other stakeholders submitted a pollutant reduction or management plan, called a Total Maximum Daily Load (TMDL), to the US Environmental Protection Agency (EPA). This plan identifies sources of major pollutants, creates goals for pollution reduction for impaired streams, requires permitted entities to meet these pollution reductions over time, and informs management actions that can be taken to help our rivers meet water quality standards. Pollutants included in this plan are bacteria, total phosphorus, and total suspended solids (turbidity); all chronic sources of pollution for the Menomonee River Watershed and the Milwaukee River Basin. The EPA accepted the plan in 2018, which represents a major regulatory milestone in the effort to curb pollution in the Basin.

KINNICKINNIC RIVER WATERSHED

D

WATERSHED OVERVIEW





KINNICKINNIC RIVER WATERSHED QUICK FACTS

RIVER MILE FACTS

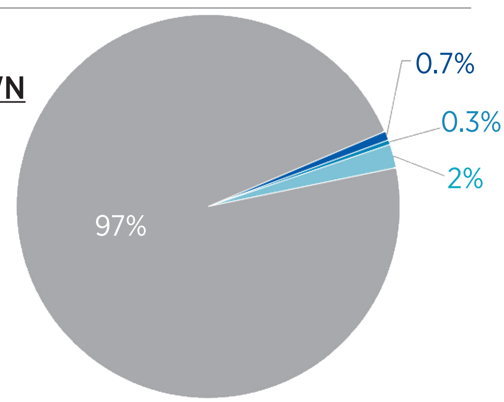
37 mi.
total miles

0 mi.
of trout streams

19 mi.
of impaired waters

LAND USE BREAKDOWN

- Agriculture
- Wetland
- Grassland/Forest
- Urban/Developed

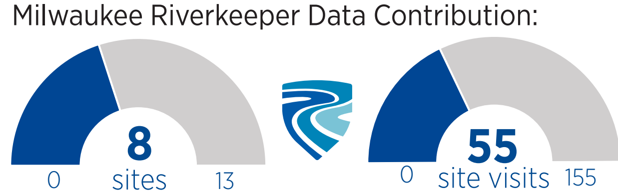


2017 MONITORING FACTS

13
total sites

155
total site visits

Milwaukee Riverkeeper Data Contribution:



Other Data Contributors:

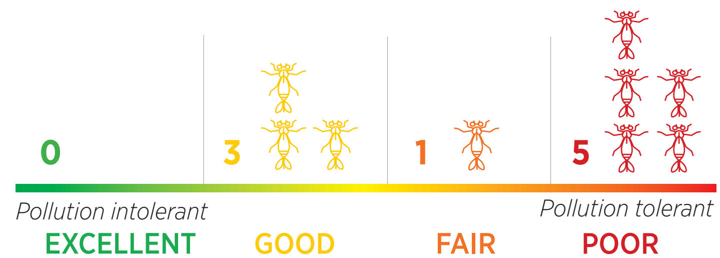
2017 DATA SUMMARY

Average Macroinvertebrate Biotic Index Score

1.39

The "Macroinvertebrate Biotic Index Score" measures the composition of stream invertebrates that are present. A high Biotic Index indicates a healthy stream. 13 samples were collected during the 2017 monitoring season.

Macroinvertebrate Types Observed Across all Surveys



In 2017, the Kinnickinnic River Watershed received a D (65.83%) for overall water quality. This grade is the lowest within the entire Basin; however, it is a notable improvement from last year when the Watershed received an F (59.94%). There were several improvements in water quality parameters that impacted the overall grade improvement between years, however turbidity was most influential with a grade increase of around 13%.

When comparing the 2017 water quality grades between Watersheds, the worst water quality parameters for the Kinnickinnic River Watershed were chloride and bacteria, which received a D- (60.71%) and an F (26.35%), respectively. These were the lowest grades observed for these water quality parameters in the entire Milwaukee River Basin. The low grades observed for these water quality parameters are likely related to several drivers, including dense urban land use, human activities, and failing infrastructure.

Land use throughout this Watershed and within the riparian corridors is nearly all urban/developed (~97% and ~85%, respectively), resulting in large areas of highly impermeable surfaces that send polluted runoff to streams. Rain events have the potential to introduce large loads of chloride from salted roadways and other paved surfaces directly into waterways via runoff. When the concentration of chloride present within the environment begins to exceed standards, it becomes a detriment to aquatic life, terrestrial ecosystems, infrastructure, and both surface water and groundwater quality. Reducing the amount of road salt being applied to surfaces could reduce chloride contamination in this Watershed and throughout the Basin.

Similarly, precipitation, in combination with degrading sewer infrastructure, may contaminate local waterways with raw sewage that contains high loads of bacteria as well as related viruses and pathogens. This not only poses serious risks to public health, but also hinders quality of life and our ability to recreate in these streams as envisioned in the "swimmable, fishable" goals within the Clean Water Act. Continued efforts to repair sewage and stormwater infrastructure, as well as install green infrastructure to infiltrate and filter runoff, would substantially lower the bacteria loading to the Kinnickinnic River Watershed over time.

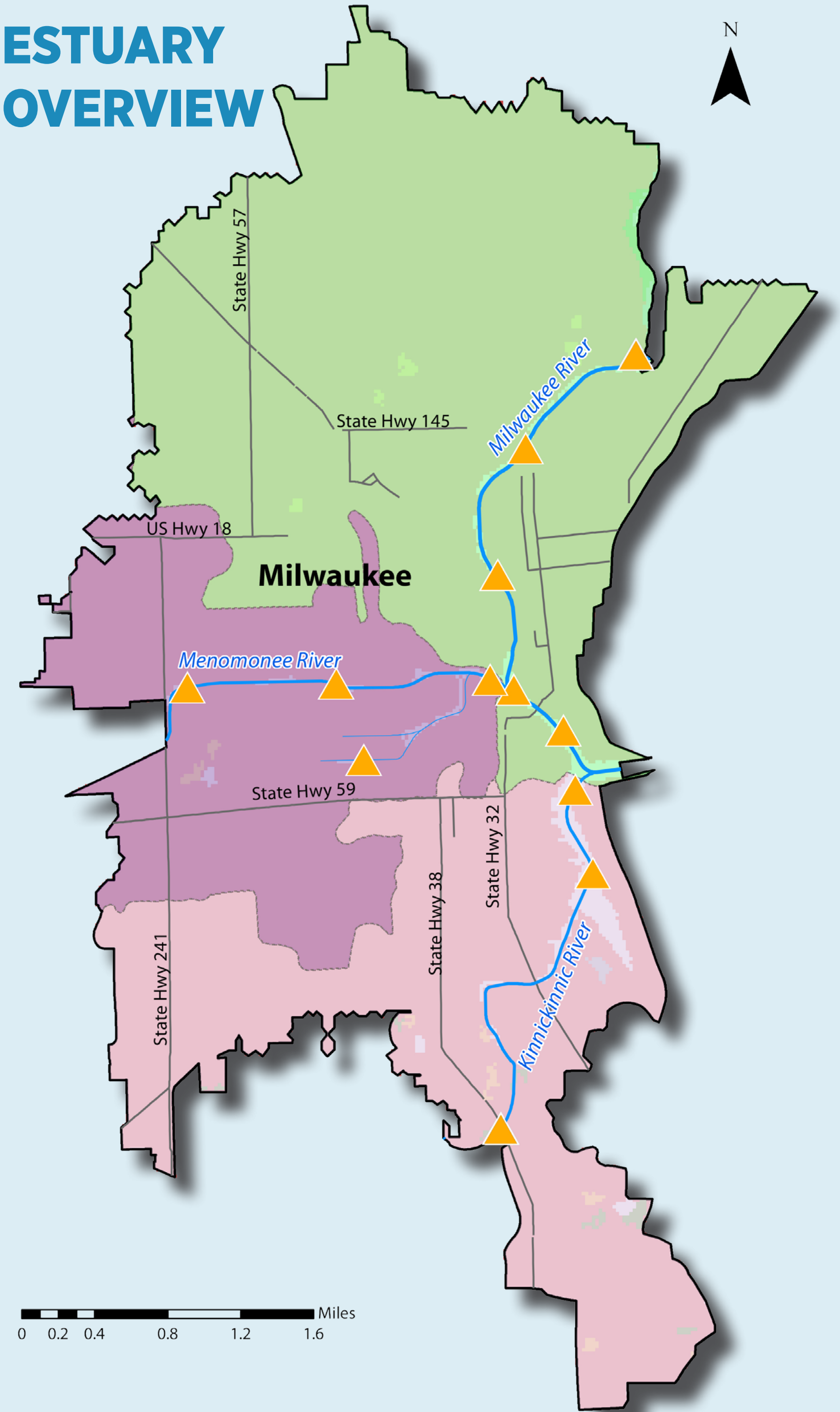
2017 WATERSHED PARAMETER GRADES

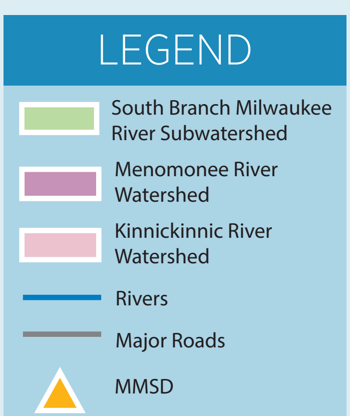
	A B C D F	2016 TOTAL	2017 TOTAL
WATERSHED	D	59.94%	**65.83%**
Temperature	A	100.00%	**100.00%**
Dissolved Oxygen	A	98.33%	**96.69%**
pH	A	100.00%	**98.60%**
Turbidity	B+	75.23%	**88.57%**
Phosphorus	F	36.21%	**41.67%**
Chloride	D-	53.72%	**60.71%**
Specific Conductivity	F	4.90%	**9.76%**
Bacteria	F	24.12%	**26.35%**

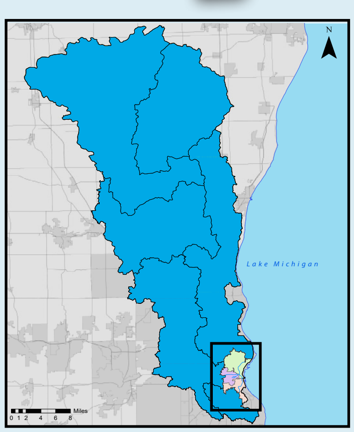
NOTE: *In 2016, we began analyzing data collected from the Milwaukee River Estuary separately from its contributing watersheds. Removing the Estuary has a relatively larger impact on the Kinnickinnic River Watershed grades since the Estuary contributes proportionally more data to this small Watershed. This change provides a more accurate picture of the Watershed's water qualilty.*

C+

ESTUARY OVERVIEW







MILWAUKEE RIVER ESTUARY QUICK FACTS

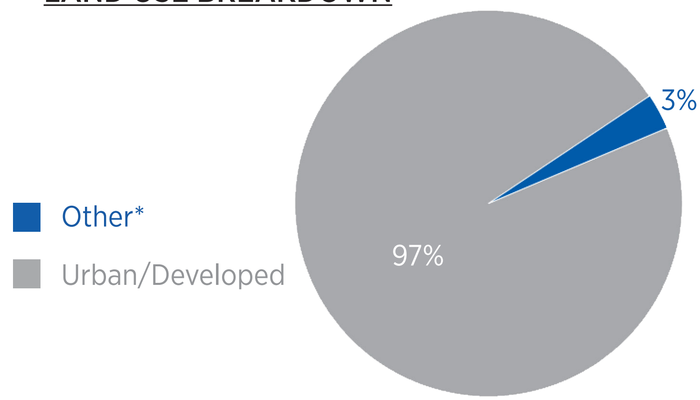
RIVER MILE FACTS

9 mi. total miles

0 mi. of trout streams

9 mi. of impaired waters

LAND USE BREAKDOWN



Includes grassland and other unidentified land uses

2017 MONITORING FACTS

12 total sites

226 total site visits

Milwaukee Riverkeeper Data Contribution:

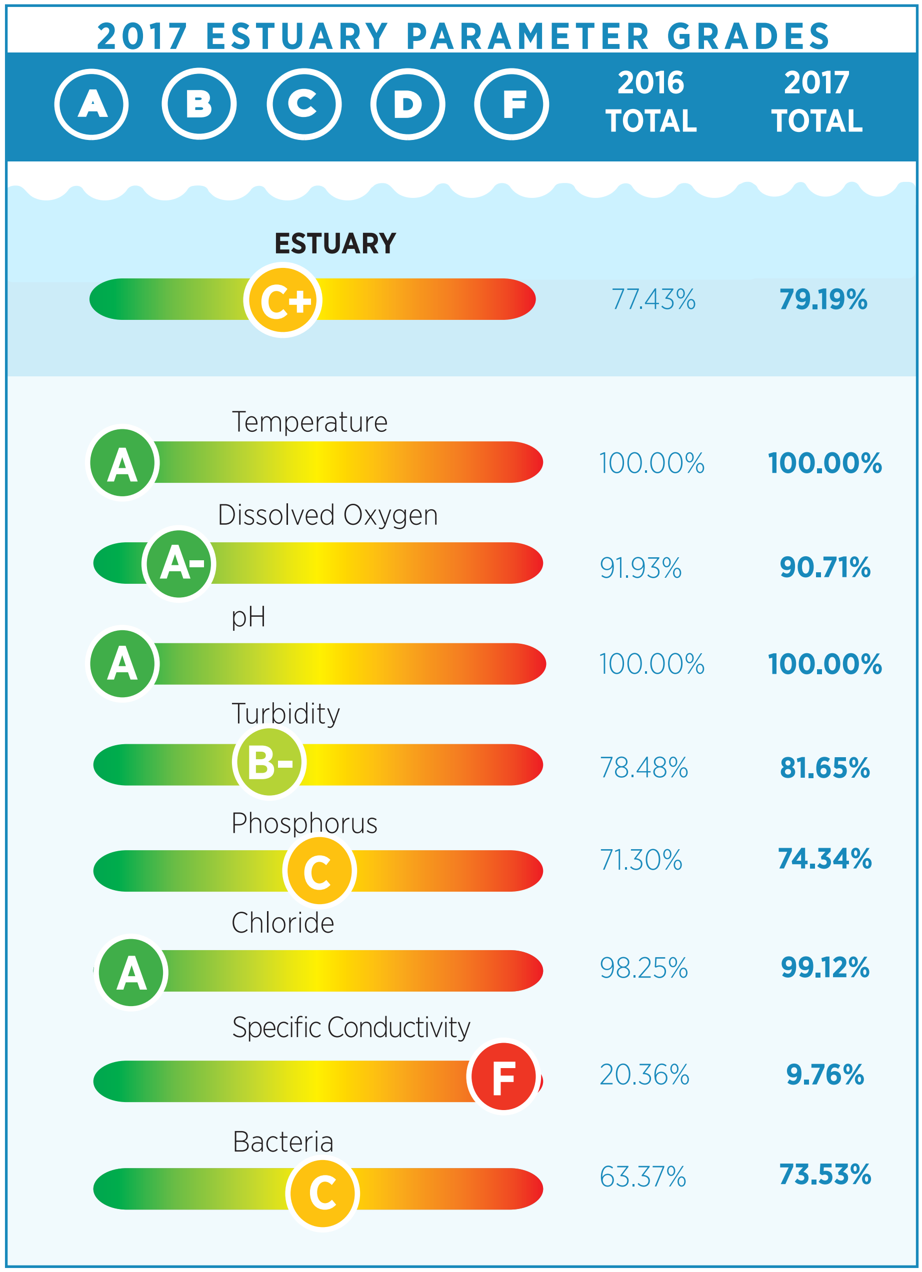
Other Data Contributors:

WHAT IS THE MILWAUKEE RIVER ESTUARY?

The Milwaukee River Estuary represents the confluence of the three major Watersheds that make up the Milwaukee River Basin and the connection to Lake Michigan. The Estuary includes the portion of these Watersheds designated by the EPA as the Milwaukee River Estuary Area of Concern. It has deeper water compared to the rest of the Basin and is regularly dredged by the U.S. Army Corps of Engineers for navigational purposes. In 2016, Milwaukee Riverkeeper began to analyze the Estuary independently of its contributing Watersheds. The relatively good water quality in the Estuary due to significant mixing with Lake Michigan inflates the overall water quality grade of its contributing Watersheds, masking some pollution problems. This system is unique compared to the rest of the Milwaukee River Basin warranting an independent analysis.

2017 DATA SUMMARY

In 2017, as in 2016, the Milwaukee River Estuary received a C+ for overall water quality, which is the second highest grade within the Milwaukee River Basin. Furthermore, 2017's grade presented a slight improvement (1.77%) over that of the previous year's grade (77.43%).



The worst water quality parameters for the Estuary were phosphorus and bacteria, which both received a C grade with approximately 70% of the data meeting standards for good water quality. Though seemingly low, the Estuary's grade for bacteria was second only to that of Cedar Creek, and its phosphorus grade was by far the highest within the entire Basin. In fact, the Estuary was the only watershed that did not receive a failing grade for phosphorus in our entire analysis. Furthermore, both parameters showed improvement from last year: the grade for phosphorus improved 3% while bacteria improved by 10%. The high observed grades for these parameters and the overall grade for the Estuary are almost certainly the result of the interactions with Lake Michigan.

Though analyzed independently in our Report Card, the Estuary is not a true Watershed. Instead, the Estuary is made up of the southernmost portions of the Milwaukee, Menomonee, and Kinnickinnic River Watersheds. These three river systems come together to form a confluence within the Estuary, which then drains into Lake Michigan. In addition to receiving water from our rivers, the Estuary also receives water from Lake Michigan. Periodic oscillation of lake levels create a phenomenon called a "seiche".

As water levels on Lake Michigan's eastern shore increase, water levels on its western shore decrease because it is a mostly enclosed body of water. Once levels on the eastern shore reach a maximum height, water will begin to move back to the west and the phenomenon will repeat in reverse. Though weather events like strong winds and rapid changes in atmospheric pressure can create large scale seiches where water is pushed from one side to the other, small highly periodic seiches are almost always occurring on Lake Michigan. The resulting effect on the Estuary is an inflow of Lake Michigan water on a fairly regular basis. Since phosphorus and bacteria levels are typically much lower in Lake Michigan compared to our rivers, the contaminants coming down from the upstream portions of the Basin are diluted in the Estuary, resulting in more samples meeting water quality standards.

AN INTRODUCTION TO FRESHWATER MUSSELS

Freshwater mussels play a number of ecologically significant roles in river environments.[1] For instance, they serve as important food sources for wildlife and support aquatic food webs. As filter feeders, they remove and store large volumes of contaminants, algae, and suspended solids from the water, in turn providing healthier environments for a number of organisms. Freshwater mussels also are relatively non-mobile, pollution sensitive, and rely on a fish host to reproduce. This makes them highly susceptible to poor water conditions, making them excellent indicators of water quality.[1]

Globally, there are approximately 1,000 species of freshwater mussels, 30 percent (300 species) of which occur in North America.[1] No region compares to North America in terms of mussel richness. Wisconsin is no exception, with 51 native species of freshwater mussels calling it home.

Unfortunately, since colonization and industrialization, many mussel species are now extinct, both globally and within North America, because of of human-induced pressures. Currently, the number of freshwater mussel species in decline globally is estimated to be approximately 70 percent.[2] Within North America alone, some 37 species (approx. 10 percent) of freshwater mussels are believed to be extinct.[3]

Fortunately, efforts to conserve and restore freshwater mussel populations are being taken by government, state, and community organizations. Of specific interest is the work being performed by the WDNR. In June of 2016, the WDNR initiated its first statewide mussel survey since the 1970's in hopes of acquiring information on the status and distribution of the state's 51 native freshwater mussel species.[2]

However, common with many large-scale projects of similar nature, the WDNR's mussel survey is burdened by the shear amount of streams that need monitoring and the lack of personnel to complete this work. In response, the WDNR formed the Wisconsin Mussel Monitoring Program to work with individuals, organizations, and communities throughout Wisconsin to engage in citizen-based monitoring of freshwater mussels. By mobilizing and advising volunteers, the WDNR is effectively increasing our knowledge of mussel population distribution statewide.

2017 FRESHWATER MUSSEL SURVEYS

In 2017, Milwaukee Riverkeeper received funding from the WDNR's Citizen Based Monitoring Network to participate in the Wisconsin Mussel Monitoring Program. In 2017 and 2018, individuals were trained in mussel monitoring protocols via volunteer workshops led by the WDNR and Milwaukee Riverkeeper. Following a training, volunteers worked with Milwaukee Riverkeeper staff to perform mussel surveys within the Milwaukee River Basin.

Mussels found while completing surveys were photographed and geotagged for later positive identification via iNaturalist, an online platform and Smartphone App for scientific findings. Images were uploaded to the Wisconsin Mussel Monitoring Program project, and assessed by State Biologist, Jesse Weinzinger, and Carroll University Professor, Dr. Todd Levine, who helped identify mussels to the lowest possible taxonomic level.

FINDINGS AND DISCUSSION

Over the course of the project, volunteers and staff searched a total of 51 sites for mussels. Of the 51 sites searched, 18 sites had live mussels present, 24 sites had shells but no live mussels, and 9 sites had no mussels present. Spatially, mussels appear to be abundant in the South Branch of the Milwaukee River and in the Cedar Creek Watersheds. Cedar Creek, in particular, appears to have thriving mussel populations. For example, on a survey of the North Branch of Cedar Creek, we found 112 live Fat Mucket mussels within 2 total hours of searching. Likewise, at a site on Little Cedar Creek we observed 53 live White Heelsplitters in less than 20 total minutes of searching.

In total, we found 13 different species of live mussels, and shells of 2 additional species. Frequently observed species included White Heelsplitters, Fluted-Shells, and Wabash Pigtoes. As these species are generally considered to be relatively pollution tolerant and widespread throughout the Midwest, it is not unexpected that we would find them throughout the Milwaukee River Basin.

Conversely, a more notable finding of our study was the discovery of live Ellipse and Slippershell mussels in a small creek in the North Branch of the Milwaukee River. Both Ellipse and Slippershell mussels are designated as a state threatened species, meaning they are on the verge of becoming endangered in Wisconsin. These mussel species prefer small, rocky streams making them particularly vulnerable to sediment inputs and pollution runoff. Identification of these populations is an exciting finding, and signifies that some areas within the Basin are maintaining very good water quality.

Though the survey produced evidence of historic mussels in the main branch of the Menomonee River, no living individuals were found during the study. The only live specimen found within this Watershed was a single Giant Floater mussel in a restored section of the Little Menomonee River. Though it's not immediately clear what has led to the extirpation of this population, poor water quality and habitat loss are likely culprits. As water quality and habitat in the Menomonee River Watershed improves, so does the likelihood that mussel populations could return. Propagation of freshwater mussels in the Menomonee River Watershed would help to reestablish a viable population in the future.

CONCLUSION

Although we did find many live mussels throughout our study, threats still loom for mussels residing throughout the Milwaukee River Basin. The majority of agricultural land within the Basin is located in the Milwaukee River and Menomonee River Watersheds. Mussels within these catchments are susceptible to a multitude of toxins from agricultural runoff, including ammonia which can come from fertilizers (and also from sewage). Likewise, the Kinnickinnic River Watershed accounts for the largest urban land use in the Basin, which is correlated with high levels of chloride from road salt, which negatively impacts mussels (especially juveniles). Baseline water quality monitoring is essential to identifying trends in these pollutants, and to assess the potential threats to mussel populations.

We need your help! Our mussel monitoring program is growing. Find out how you can get involved at milwaukeeriverkeeper.org

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Figure 1. Slippershell mussel (*Alasmidonta viridis*).
Photo Credit: Milwaukee Riverkeeper

Figure 2. Ellipse mussel (*Venustaconcha ellipsiformis*).
Photo Credit: Milwaukee Riverkeeper

Figure 3. Milwaukee Riverkeeper staff identifying mussels with volunteers.
Photo Credit: Milwaukee Riverkeeper

VOLUNTEER MACROINVERTEBRATE MONITORING

MACROINVERTEBRATES AND THE BIOTIC INDEX

"Macroinvertebrate" is a term used to describe organisms without backbones that live at the bottom of rivers, streams, and lakes, and that are visible to the naked eye. This group of organisms are effective metrics for assessing long-term health of aquatic ecosystems because many of them tolerate pollution or are sensitive to low dissolved oxygen levels. Macroinvertebrates often prefer certain habitat types as well (e.g., rocks, cobble, vegetated streambanks). While biologists may not know specific environmental factors important for each organism, general water quality can be determined by counting the types of organisms present or absent (e.g., mayflies, stoneflies, leeches). This information is compiled in a biotic index, which is a numeric scale that determines the quality of aquatic environments in terms of its macroinvertebrate inhabitants.

Milwaukee Riverkeeper volunteers use a biotic index developed by the WDNR's Water Action Volunteers Program, which yields a biotic index range from 0-4. This biotic index is based on four categories of organisms found within assessed sites (tolerant, semi-tolerant, semi-sensitive, and sensitive to pollution). Using this scale, a grade below 1 means that no organisms were present, 1-2 represents a stream with poor community health, 2.1-2.5 indicates a stream with fair community health, 2.6-3.5 means a stream has good community health, and any values 3.6 and above are representative of excellent community health for macroinvertebrates.

During spring and fall, Milwaukee Riverkeeper volunteers follow standardized protocols to collect macroinvertebrates from stream monitoring stations. Once collected, specimens are brought onto land, and with the aid of a visual chart, are identified to a general taxonomic level. After identification, organisms are separated into one of four groups depending on their tolerance to pollution. A biotic index is then calculated based on the number of organism types present in each group.

IMPACTS OF URBANIZATION ON MACROINVERTEBRATES

Since 2006, Milwaukee Riverkeeper volunteers conducted 544 biotic indices at 130 sites through the Milwaukee River Basin. The Basin-wide average for the biotic index score for this entire time period was a 2.37 indicating fair community health overall. In addition, biotic index scores ranged from higher values to lower ones when moving from upper to lower river reaches, as well as from north to south within the Basin itself. For instance, the highest average biotic indices were observed in the North Branch and East and West Branch of the Milwaukee River Watershed, which received a 2.83 and 2.42, respectively. Conversely, the Kinnickinnic River Watershed fell well below the Basin wide average with an overall biotic index of 1.73 for 2017 (Figure 1). Like many other water quality parameters dis-

MILWAUKEE RIVER BASIN: MACROINVERTEBRATE SURVEY STATISTICS (2006-2017)

	Milwaukee River North Branch Subwatershed	Milwaukee River East & West Branch Subwatershed	Cedar Creek Subwatershed	Milwaukee River South Branch Subwatershed	Menomonee River Watershed	Kinnickinnic River Watershed
Number of Measured Sites	6	27	13	40	36	10
Number of Measurements	18	102	46	216	172	49
Average Biotic Index Score	2.83	2.42	2.29	2.28	2.30	1.73

Figure 1. A summary of biotic index scores recorded by Milwaukee Riverkeeper volunteers between 2006 and 2017. A lower biotic index score can indicate a less healthy river. Scores range from 0 - 4. With the exception of the Kinnickinnic River Watershed, scores for all Watersheds and Subwatersheds indicate a fairly healthy biological community.

cussed in our Report Card, the relatively low biotic index scores observed in the southern portions of the Milwaukee River Basin are likely due to the high degree of urbanization as well as habitat modification.

A closer look at mayflies specifically underscores this trend. In 2017, mayflies were observed more frequently in samples taken from sites within less urbanized watersheds (Figure 2). Since mayflies are relatively pollution sensitive, this further suggests that urbanization is having a negative impact on water quality within the Milwaukee River Basin.

AVERAGE OCCURRENCE OF MAYFLIES

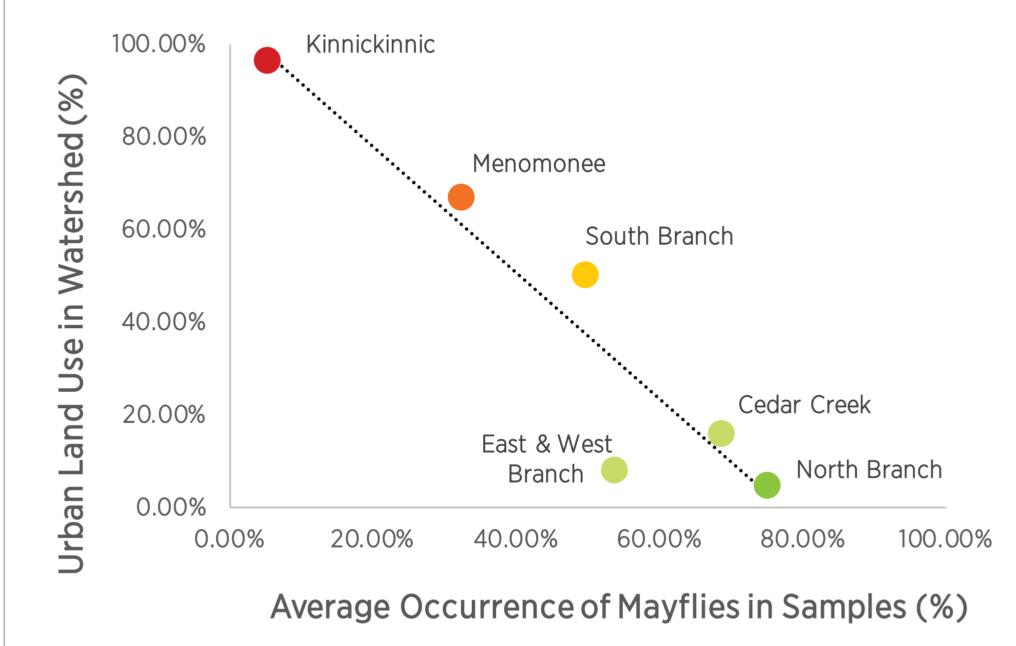

Figure 2. A graph depicting the relationship between urban land use in a watershed and the frequency of collection of mayflies in our 2017 samples. Mayflies were collected less often in more urbanized river stations.

CONCLUSION

Our volunteer macroinvertebrate data indicates that the biological community is remaining fairly healthy in much of the Basin. These biological results are similar to the Basin's overall chemical water quality, which consistently receives average grades. Both metrics suggest that continued effort needs to be put towards improving water quality within the Milwaukee River Basin. This is especially true in urban areas where macroinvertebrate biotic index scores and water quality grades tend to be the lowest.

Milwaukee Riverkeeper's macroinvertebrate data provides a biological context to help us better understand the overall health of the rivers and streams within the Milwaukee River Basin. Unlike chemical parameters that can change drastically within a short period of time due to weather and conditions, sustained pollution is required to negatively impact macroinvertebrate populations. Continued monitoring of macroinvertebrates is crucial in understanding if chemical conditions are negatively impacting biological communities and to improving our understanding of water quality within the Milwaukee River Basin.

Learn more about macroinvertebrates and how you can contribute to our work. Visit milwaukeeriverkeeper.org and sign up to become a volunteer water quality monitor!

MACROINVERTEBRATES FOUND IN THE MILWAUKEE RIVER BASIN (2017)

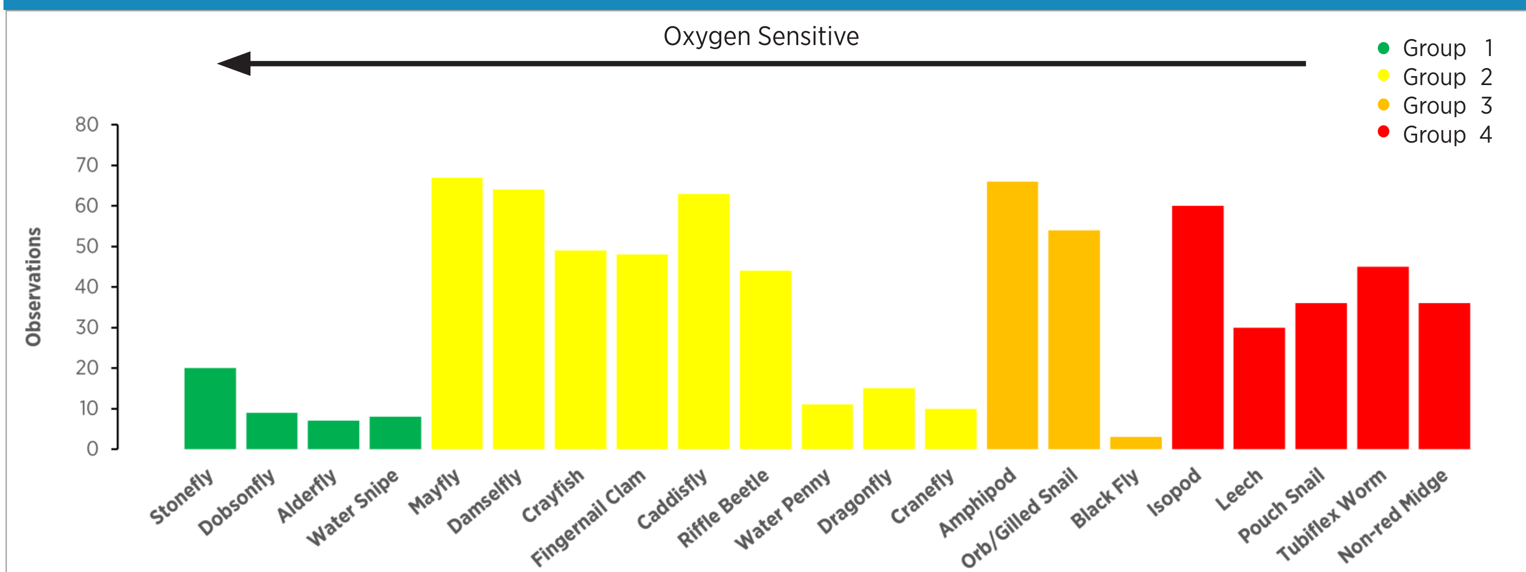

Figure 3. A bar chart displaying the total number of observations of each organism found during the 2017 macroinvertebrate monitoring season. Bar color refers to each organism's classification within the WDNR biotic index, where organisms in group four are pollution tolerant and organisms in group one require very good water quality.

AN INTRODUCTION TO MICROORGANISMS

Written by: Ryan Newton, PH.D., M.S.C.E

Microorganisms are everywhere, on and in nearly everything on Earth. This unseen world contains the most abundant and diverse set of organisms on this planet, yet we know relatively little about them, especially those organisms that do not make us sick. Bacteria are one domain of the microbial world, and this domain contains household names like *E. coli*, *Salmonella*, and *Lactobacillus.* Some of these organisms are also associated with area waterways. For instance, *E. coli*, a common bacterium in mammal guts, regularly makes appearances in the news for its unwanted presence at local beaches. When in high enough concentrations, *E. coli* is an indicator of significant fecal pollution and a reason to avoid contact with those waters. Although *E. coli* is not common to lakes and rivers, many other microbes ARE native residents of these ecosystems. In fact, >1 million bacteria per mL (1 ounce = 29.6 mL) are present in virtually every river and lake on this planet, and these freshwater ecosystems are their primary habitat on Earth. This means that Lake Michigan contains roughly $5x10^{18}$ or 5 million trillion bacteria. My hunch is that you (the reader) would not be able to name any of these bacteria? In large part, this is because many of these microbes do not have names or were only identified and named in the past 10 years. There is so much yet to be understood about the microorganisms in freshwater!

HOW DO WE IDENTIFY MICROORGANISMS?

Many microorganisms are difficult to grow in the laboratory, so we as a scientific community have only begun to appreciate the immense diversity of the microbial world. This appreciation, in large part, has been driven by new technologies in molecular biology, genomics, and computing resources. It is now quite possible to identify hundreds to thousands of bacteria in a water sample just via their DNA signatures. Remember, >1 million bacterial cells are in every mL of water, so we have a long way to go to fully characterize these communities, but as each year passes, we are capable of "seeing" deeper into this hidden world.

Last year, my laboratory teamed up with some great Milwaukee Riverkeeper scientists to gather 80 water samples from 16 Milwaukee-area rivers and streams. As a team, we measured a number of water quality parameters, such as those that go into making the Milwaukee Riverkeeper Report Card, and collected samples for bacterial community composition analysis. You can think of this analysis as akin to counting the number of different plants or birds in a forest. Basically, we capture, identify, and count the various bacterial species present in a water sample. I have been working on lake microbial communities for about 15 years, and it still blows my mind that this now somewhat routine analysis is even possible! Here is the basic process. First, we pour a few hundred milliliters of water onto a filter with pores that are so small that most bacteria cannot pass through, but the water does, effectively trapping and concentrating the bacteria onto the filter. We then extract DNA from the bacteria on the filter and amplify one particular gene (the 16S rRNA gene) that is present in all bacteria (using a technique called polymerase chain reaction or PCR). At this point we have a single tube for each sample containing only these genes for all of the bacteria in the original water sample. We then use a DNA sequencing machine at the Great Lakes Genomics Center (called Ilumina) to obtain DNA sequence information for 10s to 100s of thousands of these genes in each sample. As it turns out, most bacterial species have a unique 16S rRNA gene sequence (i.e,. the order of the ~1500 nucleotides (ATCG) in each bacterial species is unique). Once we have the sequence information in hand, we compare it to databases built from the same type of data collected from environments all over the world. This comparison allows us to identify many of the bacteria in our river samples. Many bacteria remain anonymous, only known to us by their unique DNA-based identities.

COLLABORATION WITH MILWAUKEE RIVERKEEEPER

For our project with Milwaukee Riverkeeper, we wanted to use bacterial community data to identify sewer water contamination in each of the 16 streams tested. These sequence-based technologies allow us to assess dozens of sewer-associated bacteria taxa at one time, providing a robust signal for the presence and degree of sewer water contamination in the river at the time of sampling. Previously, in conjunction with Dr. Sandra McLellan's laboratory at UW-Milwaukee, we have shown that there is a unique community of microorganisms living in sewer pipes. Many of these bacteria are not typical of natural rivers or lakes and so we can use their presence to track sewer water contamination. Based on the presence of these sewer inhabitants, we created an index of sewer water contamination and gave each river site a grade based on its contamination level across 5 sam-

ABOUT THE AUTHOR

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Ryan Newton is an Assistant Professor in the School of Freshwater Sciences at the University of Wisconsin-Milwaukee. Dr. Newton is trained as a microbial ecologist, and he has been using genomic methods to study microorganisms in aquatic ecosystems for 15 years. His lab is currently working to characterize the microorganisms that thrive in urban environments and understand how they impact human and ecosystem health in cities. In particular, Dr. Newton is interested in the interface between microbes living in wastewater pipe infrastructure and those living in rivers and lakes.

pling dates in the summer of 2017 (see table). A grade of "A" indicates low contamination and an "F" indicates high contamination. These grades are relative to each other, as we do not yet have a good handle on what constitutes typically low or high contamination levels measured with these genetic methods. Check out the grades in the associated table to see our results and the rest of this article to get to know more about a few of our Milwaukee-area river bacteria.

This project was made possible by a grant from the Fund for Lake Michigan. Thank you to them for all that they do to support Lake Michigan research and restoration!

WATERSHED SEWAGE CONTAMINATION

SAMPLE STATION	WATERSHED	GRADE
Cedar Creek at Covered Bridge	Cedar Creek	A
Mole Creek at Maple Road	South Branch Milwaukee	A-
Indian Creek Downstream of Bradley Road	South Branch Milwaukee	A-
East Branch Milwaukee River at County Highway S	East & West Branch Milwaukee	B+
Ulao Creek at Bonniwell	South Branch Milwaukee	B
Pigeon Creek at Highland Road	South Branch Milwaukee	C+
Riveredge Creek at Hawthorne	East & West Branch Milwaukee	C+
Unnamed Tributary 100 ft West of Townline Rd	East & West Branch Milwaukee	C+
Willow Creek	Menomonee	C
Little Menomonee River at Milwaukee	Menomonee	C
Dretzka Park Creek at W Bradley Road	Menomonee	C
Nichols Creek Downstream of County Highway N	North Branch Milwaukee	C
Underwood Creek at Gravel Shoals	Menomonee	C
Batavia Creek at South 28th	North Branch Milwaukee	D+
Kinnickinnic River Downstream of 6th Street	Kinnickinnic	D
Wilson Park Creek at 20th and Wilson Park	Kinnickinnic	D-

Figure 1. Letter grades were assigned to streams based on the presence of certain groups of bacteria. Lower grades indicate a higher likelihood of sewage contamination.

GET TO KNOW YOUR RIVER BACTERIA!

Limnohabitans curvus

This bacterium is one of the most abundant bacterial species living in surface freshwaters (rivers, ponds, lakes) around the world. Freshwater rivers and lakes are its natural habitat, and it has been detected in these ecosystems on all continents. In this study, *L curvus* was, on average, the most abundant bacterium across all river sites and was found in all samples. Despite this ubiquity, *L. curvus* was only identified and described by scientists in the late-2000s, so fairly little is known about its activities. Generally, the *Limnohabitans* genus contains a diverse set of bacterial species that are capable of rapid growth and have preference for algae-derived nutrients.

Candidatus Planktophila sp. unknown

This bacterium was the 8th most abundant bacterium in our river study. It is a member of the *Actinobacteriota* phylum, which contains bacteria that produce many antibiotics and bacteria that give soil its characteristic smell. However, this microbe is not at all like its cousins. Its primary habitat is lakes and rivers, and it is present in all typical surface freshwaters on Earth. It is also extremely small, having cell diameters <1 um, and one of the smallest genomes of any free-living organism on the planet. You many have noticed its unusual name. This bacterium has never been brought into laboratory culture (its hobby: befuddling scientists), and so it cannot be named officially (the *Candidatus* designation refers to candidate name). Let us know if you figure out a way to isolate and grow it!

Arcobacter defluvii

This bacterium is one of the most abundant bacteria in sewage. Our previous studies indicate it is likely a resident of sewer pipes in modern wastewater infrastructure and is found in these pipes all over the world. My lab likes to think of this genus as the "microbial pigeon or squirrel". It loves living in cities! This bacterium was only recently isolated and described (in 2011; Collado et al.), so why it is so common to sewers is not clear. The genus *Arcobacter* also contains several human and animal pathogens that are commonly associated with food-borne illness resulting in gastrointestinal issues. *Arcobacter* is not common to most surface water ecosystems, so its presence, especially in urban areas, is likely the result of contamination from sewer water. In this study, *A. defluvii* was identified in 76 of 80 samples.

OUR WATER QUALITY PARAMETERS

Below are descriptions of water quality parameters used for the Report Card. Water quality data was assessed against targets and goals as described below to determine the health and condition of our waterways. Where there is a regulatory standard or Federal guidance for a parameter, that is generally listed as the goal. In some cases, we have created our own targets based on what we feel is the reasonable potential of our streams to support fish and recreational activities.

It should be noted that WDNR and Milwaukee Riverkeeper volunteer baseline data was only analyzed from May – November. MMSD, on the other hand, collects data year round. This heavily impacted our final chloride and conductivity grades. Also, MMSD confines their monitoring to sites in the Menomonee and Kinnickinnic River Watersheds, and the southern portion of the South Branch Milwaukee River Subwatershed. Hence, the grades in the southern half of the Basin were heavily skewed towards MMSD data and grades for the upper half of our Basin had comparatively fewer data points.

DISSOLVED OXYGEN

Dissolved oxygen (DO) is a measure of the amount of oxygen dissolved in a volume of water. The amount of oxygen found in our rivers depends on atmospheric exchange (generally influenced by a stream's velocity and substrate), and on water temperature. Oxygen is essential for every organism's survival in some concentration. Therefore, not only is DO an important water chemistry parameter, it also limits habitat.

Milwaukee Riverkeeper believes that all streams in the Milwaukee River Basin are capable of supporting existing WDNR standards for warm water sport and cold water fisheries. For streams designated as Warm Water Sport Fisheries, a standard of 5mg/L was used to assess if they were meeting our DO goal. Likewise, a standard of 6mg/L was used to assess if streams designated as Cold Water Fisheries were reaching DO targets. Finally, many streams and stream segments in the urban portion of the Milwaukee River Basin have regulatory variances (per State of Wisconsin Administrative Code) allowing DO concentrations as low as 2 mg/L. This is suitable only for the most pollution tolerant fish species. Therefore, we did not assess variance streams to variance standards.

WATER TEMPERATURE

Each aquatic organism's survival is limited by its tolerance to changes in water temperature. As a result, temperature ranges can be used to classify aquatic ecosystems where drastic changes in water temperature can have significant impacts on biodiversity.

Milwaukee Riverkeeper believes that all streams in the Milwaukee River Basin are capable of supporting existing WDNR standards for warm water sport and cold water fisheries. For streams designated as Warm Water Sport Fisheries, a standard of 31.7 C was used to assess if they were meeting our temperature goal. Likewise, a standard of 22 C was used to assess if streams designated as Cold Water Trout Fisheries were reaching temperature targets. We did not assess variance streams to variance standards.

pH LEVEL

pH is a measure of acidity, or the amount of hydrogen (H+) ions in water. pH ranges from 0 to 14 (0 being the most acidic, 14 being the most basic) with a value of 7 representing a "neutral" solution. Milwaukee River Basin streams generally run on the basic side of neutral, with values typically between 7 or 8 on the pH scale. It is generally accepted that a pH range of 6-9 can support a healthy aquatic ecosystem.

TURBIDITY

Turbidity, or water clarity, affects both the light and energy inputs available to aquatic ecosystems. Our volunteers measure turbidity using transparency tubes. These are clear, plastic tubes that are filled and/or emptied of stream water until they reveal a black and white pattern on the bottom of the tube (similar to a lake secchi disc). A height of at least 54.7 cm of stream water in a 120 cm transparency tube indicates healthy water. A turbidity level of <10 NTU is ideal for aquatic life, and was used as the target for stream health. MMSD does not use transparency tubes but instead uses sensors to directly test the turbidity values of water in units of FNU (a similar turbidity unit to NTU). A turbidity level of <10 FNU was used as a target for MMSD data.

PHOSPHORUS

Phosphorus (measured as Total P) is an essential nutrient for plants, animals, and aquatic life. Phosphorus is typically low to absent in natural freshwater systems. Human activities have led to large inputs of phosphorus into our rivers and lakes. These activities include fertilization of lawns and fields, sewage treatment discharge, and the addition of phosphorus into our water supply as an anti-corrosion inhibitor for old, lead pipes. Excess phosphorus entering our waterways causes growth of nuisance algae as well as a cascade of water quality problems. A subset of Milwaukee Riverkeeper volunteers take monthly water samples that are shipped to the State Lab of Hygiene for total phosphorus analysis. These sample results are assessed against Wisconsin phosphorus standards, which are 0.075 mg/L for smaller streams and 0.1 mg/L for larger rivers and the Milwaukee Estuary.

MACROINVERTEBRATES

To assess aquatic macroinvertebrates, Milwaukee Riverkeeper volunteers use a simple biotic index, developed by a group of Wisconsin scientists, which is specifically designed for streams in Wisconsin. Index score classifications range from Good-Fair-Poor. Our target for sites in the Milwaukee River Basin is a "good" classification. Because macroinvertebrates cannot readily migrate like fish, they provide a good overall indicator of the health of a certain stream segment and tend to be classified per tolerance to a range of oxygen conditions.

CHLORIDE

High chloride concentrations in rivers and streams are toxic to aquatic organisms. Road salt runoff constitutes a large source of chloride. Elevated levels of chloride can disrupt an organism's ability to maintain a natural internal water balance, which leads to impaired survival, growth, and/or reproduction. The WDNR has set an acute chloride standard at 757 mg/L and a chronic chloride standard of 395 mg/L as targets for healthy streams. These levels recognize that high levels of chloride can be acutely or instantly toxic to fish, but that lower levels of chloride over a longer period of time or chronic exposure can be just as toxic. Chloride data was assessed against these targets to determine grades. Grades for acute and chronic criteria were averaged to determine an overall grade.

CONDUCTIVITY

Conductivity is a measure of the ability of water to pass an electrical current. Conductivity in water is affected by charged particles (ions), which can be both positive (cation) and negative (anion). Anions include chloride, nitrate, sulfate, and phosphate. Positive ions include sodium, magnesium, calcium, iron, and aluminum. Conductivity in streams is naturally affected by geology. Bedrock streams tend to have lower conductivity whereas streams passing through clay soils tend to have higher conductivity. Anthropogenic discharges to streams -- such as discharge of industrial waste (e.g., heavy metals), sewage, or other "charged" contaminants such as chloride, phosphate, and nitrate -- can raise conductivity. A conductivity reading of 150 - 500 µS/cm provides for a healthy aquatic ecosystem with mixed fisheries according to Federal guidance, and this threshold was used as the target for determining water quality grades for this parameter.

BACTERIA

High bacteria concentrations impact not only stream health, but also human health. Regulatory agencies such as MMSD and WDNR regularly test for fecal coliform and *E. coli* bacteria in surface waters. According to State of Wisconsin Recreational Use Standards, fecal coliform levels should never exceed 200 CFU/100 mL (colony forming units/100 milliliter sample) in waterways, and the EPA established an *E. coli* standard of 235 CFU/100 mL for beaches. The percentage of samples meeting these recreational health targets was used to determine water quality grades for bacteria. Waters were not assessed to variance standards.

TARGETS AND GOALS

DISSOLVED OXYGEN
Warm Stream ≥ 5.0 mg/L
Cold Stream ≥ 6.0 mg/L

WATER TEMPERATURE
Warm Stream < 31.7°C
Cold Stream < 22.0°C

TOTAL PHOSPHORUS
Large Stream < 0.1 mg/L
Small Stream < 0.075 mg/L

pH 6 - 9

TURBIDITY
< 10 NTU
< 10 FNU

CONDUCTIVITY 150-500 µS/cm

CHLORIDE
Chloride (Acute) < 757 mg/L
Chloride (Chronic) < 395 mg/L

BACTERIA
Fecal coliform < 200 CFU/100 mL
E. coli < 235 CFU/100 mL

MACROINVERTEBRATES
"Good"

	Overall Grade	Water Temp	DO	pH
Milwaukee River Basin				
Percentage*	71.40%	99.79%	91.89%	99.69%
Letter Grade	C-	A	A-	A
Milwaukee River Watershed				
Percentage	71.36%	99.51%	89.74%	99.80%
Letter Grade	C-	A	B+	A
North Branch Milwaukee River Subwatershed				
Percentage	72.76%	100.00%	81.63%	100.00%
Letter Grade	C-	A	B-	A
East and West Branch Milwaukee River Subwatershed				
Percentage	84.40%	96.97%	96.81%	100.00%
Letter Grade	B	A	A	A
Cedar Creek Subwatershed				
Percentage	80.96%	100.00%	91.14%	100.00%
Letter Grade	B-	A	A-	A
South Branch Milwaukee River Subwatershed				
Percentage	67.85%	100.00%	88.78%	99.74%
Letter Grade	D+	A	B+	A
Menomonee River Watershed				
Percentage	68.78%	100.00%	94.03%	99.74%
Letter Grade	D+	A	A	A
Kinnickinnic River Watershed				
Percentage	65.83%	100.00%	96.69%	98.60%
Letter Grade	D	A	A	A
Milwaukee River Estuary				
Percentage	79.19%	100.00%	90.71%	100.00%
Letter Grade	C+	A	A-	A

Percentage of data points that meet the water quality standard or goal for each individual parameter

Turbidity	Phosphorus	Chloride	Specific Conductivity	Bacteria
76.17%	48.33%	90.06%	6.00%	52.13%
C	F	A-	F	F
74.29%	38.52%	97.46%	6.67%	53.37%
C	F	A	F	F
95.12%	36.17%		3.70%	
A	F	**	F	**
87.64%	52.83%		17.24%	
B+	F	**	F	**
92.75%	37.50%	100.00%	0.00%	81.25%
A-	F	A	F	B-
65.10%	36.76%	97.24%	6.54%	50.34%
D	F	A	F	F
71.32%	47.98%	91.10%	1.88%	45.86%
C-	F	A-	F	F
88.57%	41.67%	60.71%	9.76%	26.35%
B+	F	D-	F	F
81.65%	74.34%	99.12%	9.76%	73.53%
B-	C	A	F	C

***Data not collected for this individual parameter and watershed*

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