ROAD SALT REPORT

Prepared by:
Rick Wenta, Environmental Protection Lead Worker

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Public Health
MADISON & DANE COUNTY
Healthy people. Healthy places.

OVERVIEW

The Wisconsin Department of Transportation (DOT) began using road salt to deice state highways in the early 1950s. Its use became so popular that by 1956, the DOT had implemented a “bare pavement” policy for state highways.

The intensive salting and plowing efforts coming from the bare pavement policy fueled motorists’ expectations of favorable winter driving conditions, creating a demand for increased road maintenance that persists to this day. However, because of economic and environmental concerns, salt use reduction efforts began at the state and city level in 1973. At the same time, the Madison Common Council directed the Madison Department of Public Health (now Public Health Madison & Dane County) to monitor the effects of road salt on the Yahara Lakes and submit an annual report.

This report includes most of the main topics and data collected from Public Health’s salt monitoring program.

DISCUSSION

HOW ROAD SALT WORKS

Driving on snowy roads creates a layer of ice on the pavement. Plowing alone is not enough to prevent ice from forming or bonding to the road. Therefore, deicers are used to prevent or remove this bond. When water freezes, the molecules line up in a lattice structure. This is because water is polar, with a positive charge on one side and a negative charge on the other. Deicers act as a foreign body, preventing this lattice from forming and lowering the freezing point of water.

CHLORIDE NEGATIVELY AFFECTS THE ENVIRONMENT

When road salt (sodium chloride) is applied to a snowy roadway, it must dissolve in water before it can melt snow and ice. When salt dissolves, it breaks up into a positively charged sodium ion and a negatively charged chloride ion. The sodium can grip onto soil particles. However, the chloride moves freely through the environment, and so is transported with rainwater into our lakes and groundwater. Chloride is not removed from the environment by biological uptake or chemical reactions, either. Therefore, their concentration in our water resources continues to grow with each salt application. The only way to reduce chloride concentration is through rainwater being added or water flowing out of the watershed.

Aquatic life

Chloride in our surface waters is toxic to aquatic life. The Wisconsin Department of Natural Resources (DNR) has set the chronic toxicity criterion for chloride to 395 mg/L. This is the maximum 4-day concentration that ensures adequate protection of aquatic life if not exceeded more than once every 3 years. Heavier, salt-laden water can also collect at the bottom of lakes and cause a condition known as meromixis, where water near the bottom does not circulate during seasonal turnover.

Drinking water

Chloride negatively affects our drinking water as well. There is no health-based standard for chloride in drinking water. However, the Environmental Protection Agency (EPA) has set a secondary standard for chloride in drinking water at 250 mg/L. Secondary standards are for aesthetic considerations, like taste and smell.

Infrastructure

Chloride also increases the corrosivity of water. Road salt causes faster corrosion of bridges, concrete roadways and structures, and automobiles. The damages caused by road salt are difficult to quantify, but the following are some examples:

- In 2015 the National Highway Traffic and Safety Administration found 2008 and earlier vehicles could experience unexpected brake failure due to corrosion caused by road salt.
- The Algo Centre Mall in northern Ontario collapsed from corrosion to steel supports caused by salt water from a leaky roof top parking lot.
- Road salt was also a contributing factor in the lead contamination of drinking water in Flint, Michigan.
- The Highway 19 bridge over the Yahara River is noticeably more corroded than just six years ago (See Figure 1).

FIGURE 1: Corrosion of Highway 19 Yahara River Bridge. March of 2013 on left, December of 2019 on right. Stalactites form at the largest fracture every winter and slowly dissolve over the remainder of the year.

ALTERNATIVE DEICERS

Even though road salt damages our infrastructure, water resources, and our environment, it is widely considered cheap and effective. Wisconsin experiences many freeze-thaw cycles throughout winter, which can cause dangerously slick roadways. Thus, some amount of anti-icing/deicing is necessary to keep roads passable for emergency equipment and commerce. Because of this, potential alternatives to road salt should be considered.

- **Chloride salts of calcium and magnesium** were some of the first alternative deicers used.
  - **Pros:** They work at lower temperatures than sodium chloride (road salt).
  - **Cons:** They still contribute chlorides to the environment. Neither is as efficient as sodium chloride either, i.e. more calcium and magnesium salt is needed to achieve the same result. It is also more expensive than road salt.
- **Calcium magnesium acetate (CMA)** is another alternative that has been used infrequently.
  - **Pros:** It is much less corrosive than chloride salts.
  - **Cons:** It is biodegradable so it exerts an oxygen demand on any water body it enters. This takes oxygen out of the lake that is needed by fish and plants. It also works at a higher minimum temperature. It also is more expensive than road salt.
- **Other less corrosive alternatives** have been developed as well. These are usually a combination of a chloride salt and an organic, phosphate, or metal component.
  - **Pros:** They are less corrosive and have less chlorides than road salt.
  - **Cons:** These still add chloride to the environment, but also add other unfavorable nutrients and metals. They usually add oxygen demand, which is detrimental for aquatic life. These are also more expensive than road salt.

REDUCING ROAD SALT USE IS IMPORTANT TO PROTECT THE ENVIRONMENT AND INFRASTRUCTURE

Because there is no accurate report of the damages caused by road salt, it remains the most commonly used deicer. If deicers are necessary for safe roads, and if road salt is the best option, then reducing the harmful effects of deicing can only be achieved by reducing the amount applied.

HISTORY OF MADISON'S ROAD SALT USE

The interstate highway system set standards and procedures for road salt use that have influenced state, county, and municipal actions.

STATE HIGHWAY MAINTENANCE SINCE 1940

In the early 1940s, state highway maintenance consisted of plowing and applying sand and other abrasives (see Figure 2). By the early 1950s, highway deicing with road salt had begun. Salt soon replaced abrasives as the preferred winter highway treatment. It was cheap, provided better traction, and required one truckload to treat the same stretch of road as eight loads of sand.

DOT introduced the bare pavement policy to protect drivers

Transportation officials throughout the northern United States believed that bare pavement was essential to protect the lives of motorists. This led The Wisconsin Department of Transportation (DOT) to adopt a "bare pavement" policy for state highways. However, maintaining bare pavement was expensive. It required continuous snow plowing all through a storm and heavy salt application (400-1200 pounds per lane mile).

Although awareness of the environmental impacts of road salt was increasing, the first reduction in salting was made to cut costs. Overtime pay and the increased cost of fuel caused by the oil embargo prompted a change in the bare pavement policy in 1973. The DOT reacted by creating three classes of highway with different levels of plowing and deicing.

The DOT officially recognized the environmental hazards of deicing salt in 1978 when it further changed the bare pavement policy. The department would now strive to use deicing chemicals more carefully. Snow was removed as quickly as possible. Salt use was limited to prevent ice bonding to pavement and to clean-up after a storm. Furthermore, application rates were limited to 300 pounds per lane mile. Handling and storage of deicing materials was also emphasized. Environmental protection was again addressed in 2002 when the DOT clarified the expectations of the bare pavement policy. The name was also changed to Passable Roadway – During a Winter Storm guideline.

Deicers are necessary for safe roads, but reducing the amount applied is important to protect our environment.

MADISON ROAD MAINTENANCE

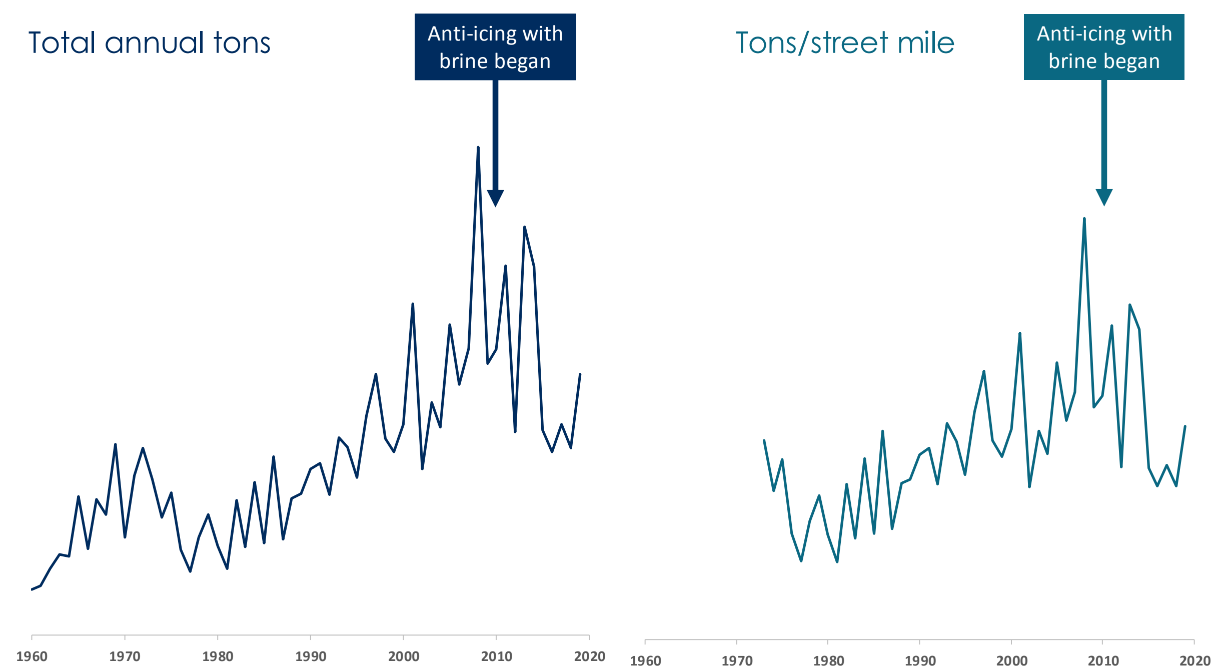
Over this 60-year time span, winter road maintenance in Madison followed a course similar to the state's, but with a heightened environmental awareness. City salt applications began in 1959. In just three years, the community voiced concern over the impacts on the environment. A study conducted by the Rivers and Lakes Commission in 1962 revealed high chloride in roadside ditches following melt water flows, but overall road salt impacts were minimal. Yet chloride levels in Lake Wingra were increasing at an alarming rate, compelling the Rivers and Lakes Commission to request a 50% reduction in road salt use in the Lake Wingra basin for the winter of 1973-74. By 1977, the salt reduction program was extended to the entire city.

A primary strategy for meeting the salt reduction goal was segmented salting. This practice involved applying salt on every other block. Traffic was supposed to carry salt residue to the untreated roadway. Although it reduced salt use, the carry-over was minimal and the process resulted in increased ice formation. It was discontinued in 1980 due to strong opposition to city-wide salt reduction.

The trend in salt use, per mile of roadway, from the winter of 1973-74 to the 1979-80 season was decreasing. It has been generally increasing since (See Figure 2). Yet, there have been many improvements in application efficiency. For example, the introduction of anti-icing with brine in 2010 appears to have increased the efficiency of salt applications and is the probably the main contributor to the dramatically lower salt use over the past five years.

Madison road salt use has increased steadily, until introduction of brine

FIGURE 2: Road salt use 1960-2019, total annual tons (left) and tons/street mile (right). While the trends appear similar there is a significant decrease in the slope when use is standardized for street miles.

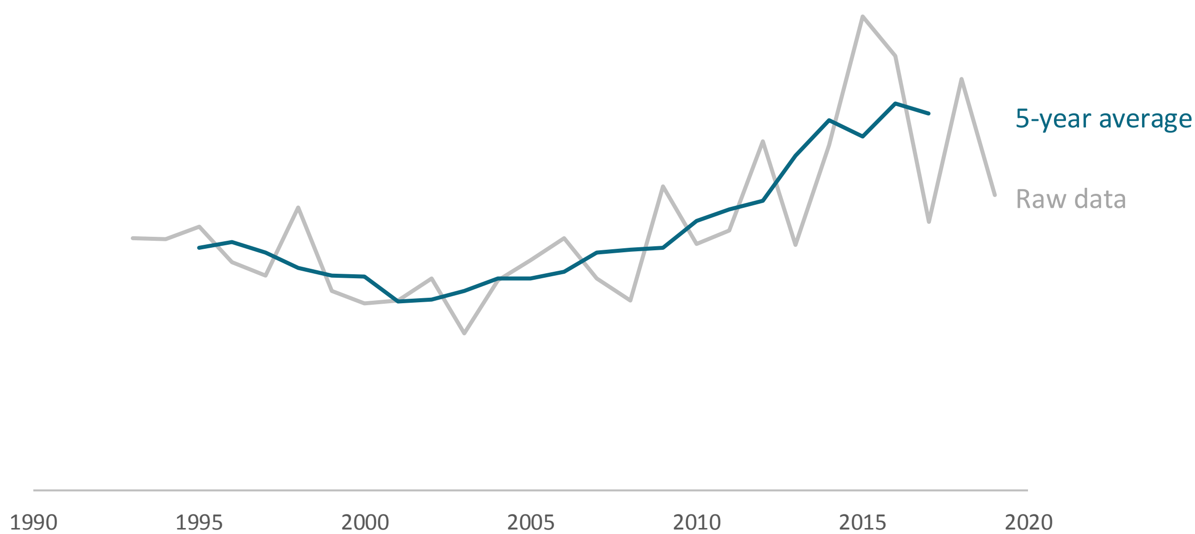


To isolate the efficacy of road salt applications, the time series of salt applied per street mile was decomposed, as a multiplicative trend, from 1993-2019. The trend was removed, leaving “seasonality” and “error”. Since there is no repeating pattern to the remaining components, error could not be removed. For the purposes of this analysis, the product of seasonality and error is equated to salt use efficiency.

The efficiency was standardized to the Winter Severity Index (WSI). (The WSI is calculated by the Wisconsin Department of Transportation – DOT to characterize the winter road maintenance demands produced by the weather.) This serves to remove the changes in deicing needs caused by changes in the weather. The resultant efficiency time series was plotted with a centered 5-year moving average to highlight the trend (see Figure 3). While there is a general upward trend starting around 2001, the slope increases markedly around 2012. This coincides with the start of anti-icing with salt brine.

Road salt use has become more efficient over time

FIGURE 3: Time series of road salt use efficacy. Centered 5-year moving average (blue) and raw data (gray).



- The complete time series of salt applied per street mile was not used because the WSI is only available for the last 26 years.
- A simple 5-year rolling average was used to decompose the salt per street mile time series.
- The salt per lane mile data set is too small to use for this analysis.

CHLORIDE TRENDS IN DANE COUNTY

YAHARA LAKES

Salt applications are the main source of chloride to our environment. Once it enters our water resources, chloride can only be removed by outflow. This occurs in two ways: flowing out through the Yahara River, or processing for drinking water (treated and discharged from the watershed by the Madison Metropolitan Sewerage District). The only other way to reduce the concentration of chloride is dilution with rainwater.

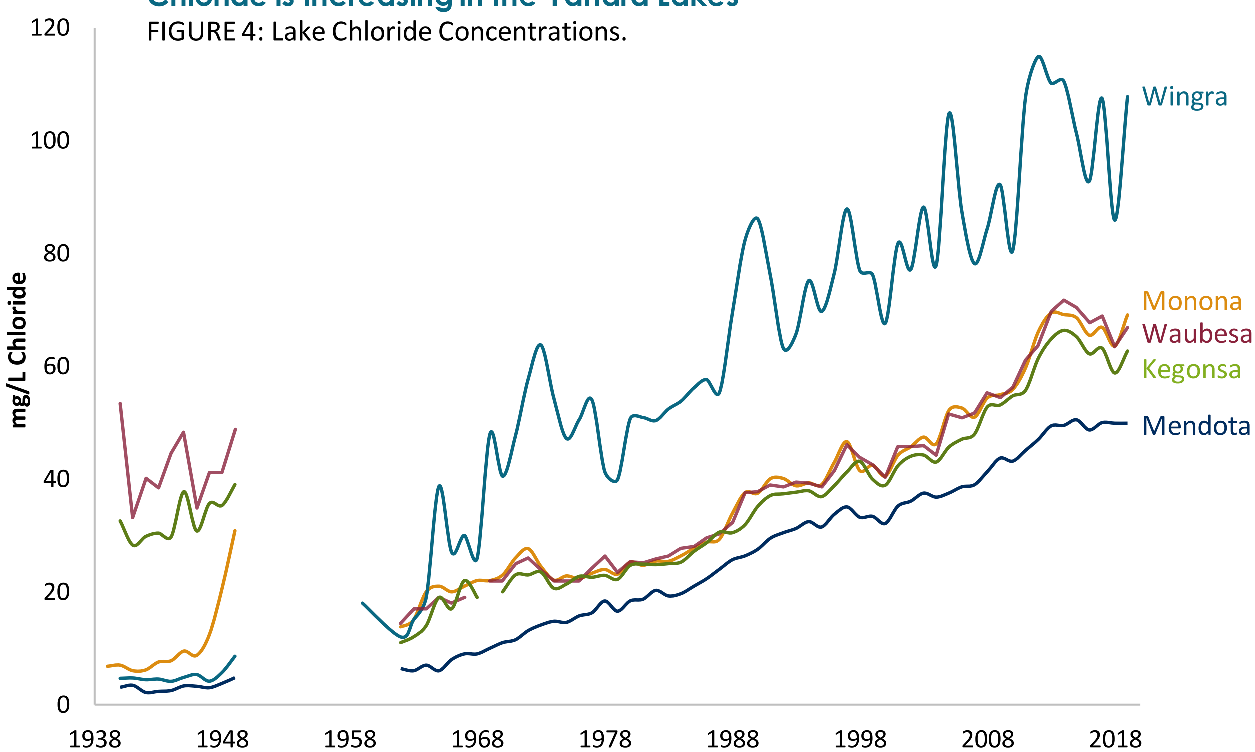
Madison has used 60% less road salt in the last five years. However, chloride concentrations in the Yahara lakes are still increasing.

While the focus of this report has always been on Madison's use of road salt, there are eight townships, two villages, three cities, and many private applicators adding chloride to the watershed. Although most agencies try to minimize salt use to reduce cost, priorities and application rates vary.

Average road salt use over the past five years is 60% lower than the previous five years. A similar comparison of lake chloride concentrations reveals Lake Wingra chloride has decreased by 5%, while the other Yahara Lakes have all increased by about 5% (see Figure 4). There are many factors contributing to this difference.

Chloride is increasing in the Yahara Lakes

FIGURE 4: Lake Chloride Concentrations.



WHY DID CHLORIDE DECREASE ONLY IN LAKE WINGRA?

Volume

Lake Wingra is much smaller than the other lakes. Therefore, stormwater dilutes the lake more easily. Also, the watershed was developed long ago, so new roads are not being built nearby, which would increase salt runoff into the lake.

Inputs from stormwater runoff and springs

There are confounding factors, though. Storm water runoff and spring inflow are the main inputs to Lake Wingra. Storm water runoff can have varying amounts of chloride, but in general, it dilutes the chloride concentration of the lake. Springs, however, often do the opposite. Springs discharge shallow groundwater to the lake. Road salt has a large impact on spring water, and so this often adds more chloride to the lake. To see how the concentration of chloride changes over time in the Yahara lakes, see the time series in the Appendix. An animated version is on the Public Health Madison and Dane County webpage.

Decrease in Madison salt use

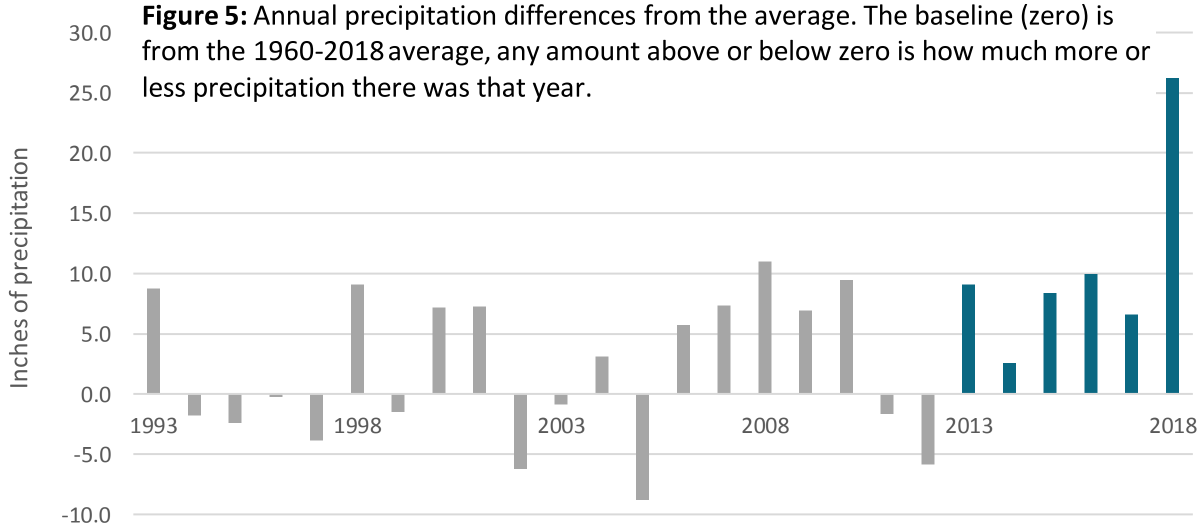
Madison has used 60% less salt per year for the past 5 years. However, this is about the same amount that was used since 1981 (8400 and 8500 tons respectively). This time span is relevant because 1980 was the last year of segmented salting, which was perhaps the most effective reduction method ever used. Since 1981, the chloride concentration in Lake Wingra has increased by over 200%. So although the chloride concentration in Lake Wingra has decreased over the past five years, further reductions in salt use are required to reduce chloride levels in the lake.

Increased precipitation

The chloride levels are also lowered by dilution. An increase in precipitation may be the main factor affecting lake chloride levels recently. Over the past five years, precipitation has been 30% higher than the 1960-2018 average (see Figure 5). In 2018, rainfall was more than 26 inches over average.

Precipitation has increased in the last 5 years.

Figure 5: Annual precipitation differences from the average. The baseline (zero) is from the 1960-2018 average, any amount above or below zero is how much more or less precipitation there was that year.



SMALL SURFACE WATERS

Small surface waters can be profoundly affected by road salt. Public Health has documented acutely toxic levels of chloride (WI Department of Natural Resources acute toxicity criterion = 757 mg/L) in several small urban waterways. The sampling protocol does not capture the peak levels, so the maximum chloride concentrations may be much higher. It should be noted that these waters receive lots of storm water, and so do not support much aquatic life. Seasonal chloride inputs are likely just one of many contributing factors to this. Data can be found at the end of this report.

Chloride has increased 200% in Lake Wingra since the 1980s; it has only begun decreasing in the last 5 years.
Further reductions in road salt use are necessary to protect our lakes.

GROUNDWATER

As previously stated, road salt applications contaminate our groundwater. Shallow groundwater is affected first and this is reflected in the chloride levels in Madison's drinking water. Chloride levels continue to increase in some City wells that draw water from both the upper and lower aquifers near main roads. Figure 6 compares past chloride concentrations in deeply cased wells, which draw water from the lower aquifer and wells with short casings, which draw water from both the upper and lower aquifers. The bisecting line represents the median concentration.

Sodium is also increasing in our drinking water, although more slowly than chloride. Average sodium concentration has risen from 6.7 mg/L to 15.6 mg/L in the past 25 years. Current median and maximum levels are 8.6 mg/L and 52.2 mg/L respectively.

Sodium and Chloride levels are increasing in Madison groundwater

Figure 6: Change in chloride concentrations in Madison drinking water wells over the past 40 years.

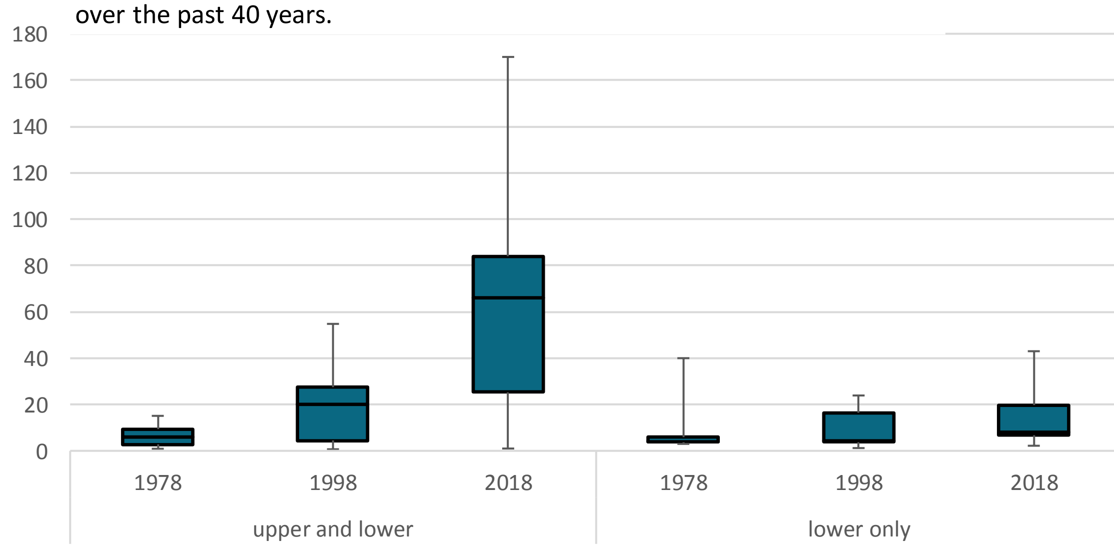


Table 1: Chloride in City wells.

Upper and lower

Year	UW6	UW9	UW11	UW12	UW13	UW14	UW15	UW16	UW17	UW18	UW20	UW23	UW25	UW26
1978	9.5	11.8	5.0	1.0	6.8	13.4	8.0	2.4	15.1	4.0	4.5	9.0	1.1*	0.9*
1998	23.7	30.9	27.8	1.2	6.6	54.7	26.5	16.5	25.9	7.6	0.7	54.8	1.2	3.8
2018	85.0	81.0	78.0	3.1	58.0	170	53.0	93.0	74.0	21.0	1.0	120*	9.0	38.0

Lower only

Year	UW7	UW8	UW19	UW24	UW27	UW28	UW29	UW30
1978	3.9	5.9	3.7	3.0*	40.0*			
1998	23.9	14.1	4.1	4.4	23.4	1.2	2.6*	4.6*
2018	18.0	25.0	9.1	6.3	43.0	2.2	7.3	6.9

*Well 23: data from 2017
*Well 24: data from 1979
*Well 25: data from 1983
*Well 26: data from 1986
*Well 27: data from 1989
*Well 29 & well 30: data from 2006

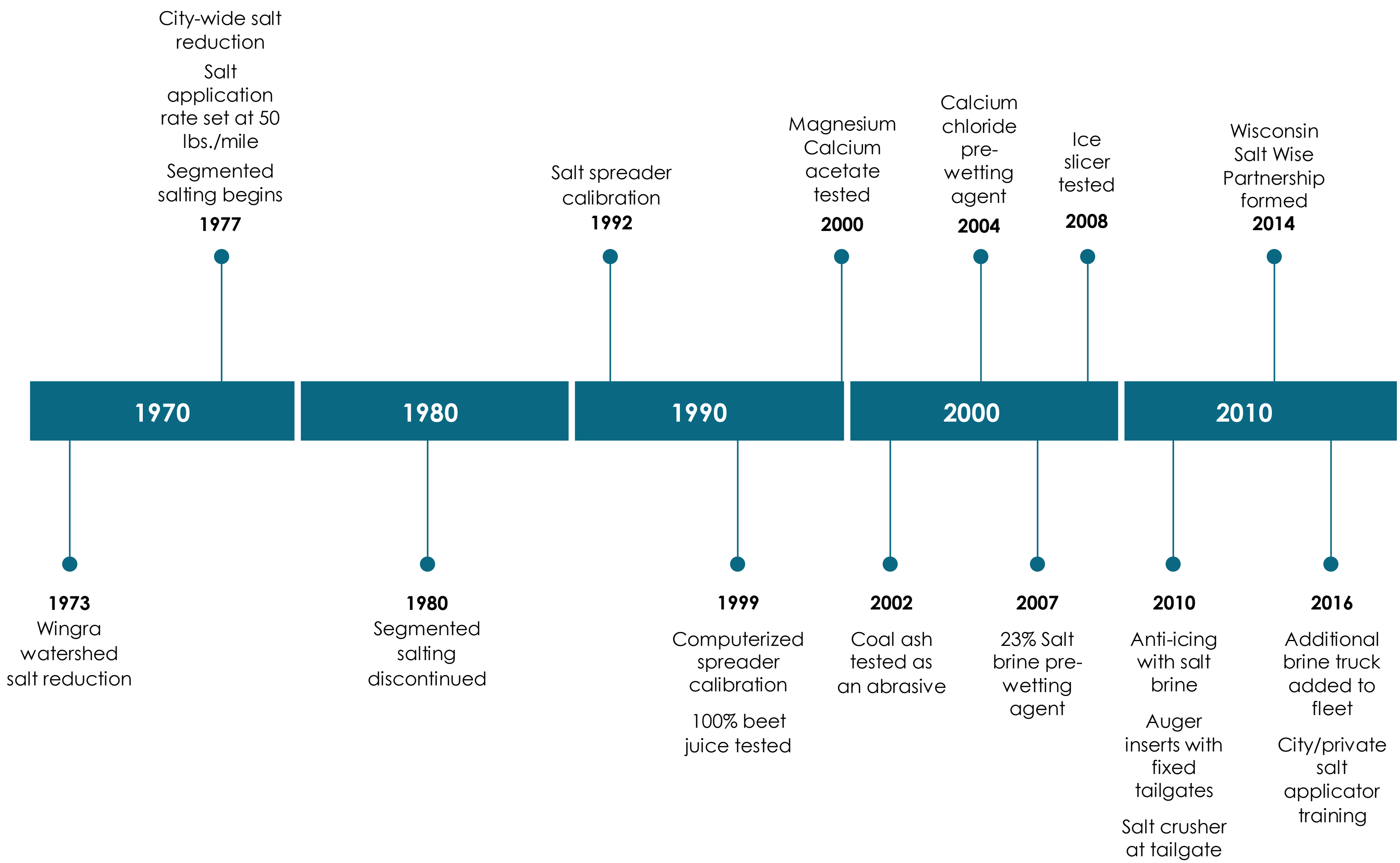
SUMMARY

The golden age of motoring began with the passage of the Highway Act of 1956, promising direct and high-speed travel throughout the nation on an interconnected system of highways. Highway maintenance standards soon rose to provide summer driving conditions in winter and deicing with road salt became the norm. Drivers quickly began to anticipate favorable driving conditions throughout the year. This expectation persists despite more than forty years of heightened awareness of the damage caused by road salt, and efforts to reduce its use.

Anti-icing with salt brine appears to have reduced the amount of salt needed for winter road maintenance. Annual salt use has declined, but it is likely not enough to lower the chloride concentration in the Yahara Lakes, and chloride continues rise in our drinking water. Further reductions are needed, along with a concerted effort by other municipalities and the private applicators in the watershed.

APPENDIX 1: REDUCTION EFFORTS

FIGURE 7: Timeline of methods and deicers tested.



APPENDIX 2: CHLORIDE TRENDS IN SPRINGS

Biannual monitoring of several springs indicates that chloride levels in shallow groundwater are also increasing, although at a slower rate than surface waters (see Figure 4).The chloride concentration of East Spring, which is the origin of the East Branch of Starkweather Creek, fluctuates widely compared to Big Spring and Nakoma Spring. This variability is likely a function of the urbanized recharge area of East Spring, as it receives a substantial portion of the runoff from the East Towne area. However, chloride has increased in all three springs since monitoring began in 1996.

FIGURE 8: Chloride trends in springs.

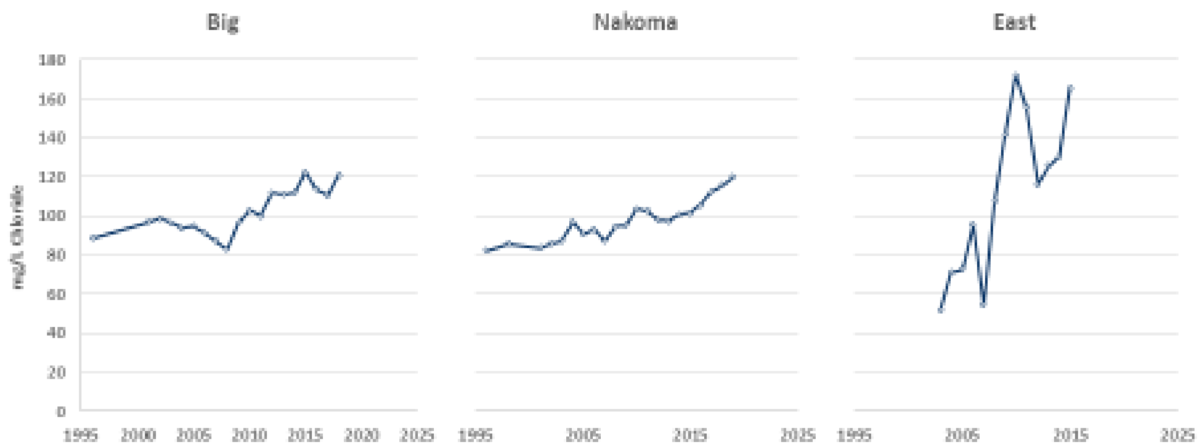


TABLE 1: Chloride trend in springs.

	Big	Nakoma	East
1996	88.6	82.3	
1998		85.6	
2001	97.0	83.8	
2002	98.5	85.8	
2003	96.5	87.0	51.6
2004	93.6	97.0	71.0
2005	94.9	90.8	72.6
2006	91.4	93.1	95.4
2007	87.1	87.1	54.3
2008	83.0	94.4	107
2009	96.2	95.0	142
2010	103	104	172
2011	100	103	156
2012	112	97.8	116
2013	111	97.1	126
2014	112	101	130
2015	123	101	166
2016	114	106	
2017	111	112	
2018	121	116	
2019		120	

During the shutdown of Unit Well 14 in early 2017, PHMDC monitored chloride concentrations and estimated discharge rates for the nearby Spring Harbor Springs. The results, tabulated below, demonstrate the movement of road salt through the soil profile to the aquifer. Shallow groundwater levels rose after the well was shutdown, influencing the flow rate. Chloride levels increased as shallower groundwater was discharged from the springs. Discharge rates decreased once the well was put back in service.

TABLE 2: Spring Harbor spring chloride during UW 14 shut down.

	Chloride (mg/L)	Discharge (ft^3/sec)
1/30/17	47.4	
2/9/17	134	1.0
2/16/17	145	1.5
2/22/17	150	1.7
3/2/17	159	1.5
3/9/17	165	1.1
3/16/17	169	1.7
3/23/17	171	0.7

APPENDIX 3: LAKE CHLORIDE (MG/L) DATA

TABLE 3: Yahara lakes chloride concentrations 1970-present.

	Yahara River	Mendota	Monona	Wingra	Waubesa	Kegonsa
Oct-70				39.0		
Nov-70					21.8	20
Feb-71				44.0		
May-71				49		
Oct-71		11		50.0		
Nov-71		12				
Feb-72		14				
Mar-72				50		
May-72		13.5	28.8	65	25.5	22
Jul-72		11				
Oct-72		14	26.5	58	25.2	23
Nov-72				58		
Jan-73				56.0		
Mar-73		13.5	25	71.0		
Apr-73		14.0	26.5	70.0	25	23
May-73		14.5				
Jun-73				64.0		
Jun-73				58.0		
Jul-73				64.0		
Sep-73				65.0		
Oct-73		14.5	22	62.0	23	24
Jan-74				63.2		
Feb-74		18.5	25	58.5		
Mar-74		10.5		51.0		
Apr-74		14.2		51.0	21	20
May-74		13.5	22	50.5		
Jun-74		15.0	22	48.0	22	20
Jul-74		15.5		50.0		
Sep-74		15.0	22	50.0	21	21
Oct-74		15.0	21	49.0	22	21
Dec-74		15.8	22	49.5	22	22
Jan-75		16.0	21.8	52.0	21.5	22.5
Feb-75		15.8	23.5	52.0	22	27.5
Mar-75		14.5	26.0	53.2	23.2	22.5
Apr-75		9.5	27.2	45.0	21.5	20.2
May-75		16.0	25.5	49.5	22.2	19.2
Jun-75		15.5		47.0	22	19
Jul-75		15.0	21	43.0	22	20
Aug-75		19.2	20.5	41.0	22	20.5
Sep-75		15.5	21.2	42.0	21.8	21.5
Oct-75		15.0	15	45.0	21.2	21.5
Nov-75		15.8	21.5	42.5	22.5	21.5
Dec-75		15.8	21	41.5	21	21.5
Jan-76		15.2	22.8	46	22	21.5

	Yahara River	Mendota	Monona	Wingra	Waubesa	Kegonsa
Feb-76		17	22	43.8	23	23.5
Mar-76		14	23	43.5	30	30
Apr-76		15.2	23.8	48	22.5	21
May-76		14.5	21	47	21	19
Jun-76		15.5	21.5	47	22	21.5
Jul-76		16.0	22	56.0	23	22
Aug-76		15.5	20	52.0	22	22
Sep-76		16.0	22	56.0	23	22
Oct-76		16.0	23	58.0	23	23
Nov-76		15.0	21	55.0	22	22
Dec-76		19.0	25	60.0	27	26
Jan-77		18.0	24	65.0	25	25
Feb-77		19.0	27	69.3	30	27
Mar-77		16.0	26	60.0	26	24
Apr-77		16.0	25	50.0	23	23
May-77		16.0	24	51.0	22	22
Jun-77		16.0	22	52.0	23	22
Jul-77		15.0	22	49.0	33	21
Aug-77		13.5	19		15	17
Sep-77		16.0	23	47.0	22	22
Oct-77		16.0	21	44.0	23	22
Nov-77		16.0	22	43.0	23	22
Dec-77		18.0	24	48.5	25	25
Jan-78		20.0	22	52.0	25	25
Feb-78		18.0	23	53.0	26	26
Mar-78		20.0	25	60.0	28	29
Apr-78		12.0	22	48.0	19	22
May-78		18.0	23	43.0	22	21
Jun-78		17.0	22	42.0	24	21
Jul-78		18.0	19	33.0	19	19
Aug-78		15.0	17	32.0	21	19
Sep-78		23.0	34	21.0	55	18
Oct-78		25.0	36	40.0	32	32
Nov-78		18.0	23	37.0	24	22
Dec-78		16.5	22	35.0	22	21
Jan-79		16.0	22	39.2	24	23
Feb-79		17.8	20	40.0	25	23
Mar-79		17.5	25	42.0	24	24
Apr-79		13.5	25	33.7	21	19
May-79		16.8	24	42.2	23	20
Jun-79		17.4	24	28.9	24	22
Jul-79		15.9	24	29.8	24	21
Aug-79		16.7	24	46.5	25	23
Sep-79		16.8	23	43.7	23	23
Oct-79		16.7	23	44.7	24	23
Nov-79		16.9	23	43.4	24	23
Dec-79		16.8	22	44.4	22	23
Jan-80		17.6	24	45.7	24	24
Feb-80		17.9	24	50.0	26	27

	Yahara River	Mendota	Monona	Wingra	Waubesa	Kegonsa
Mar-80		17.9	26	50.6	26	26
Apr-80		22.0	26	49.0	28	27
May-80		19.0	29	56.0	27	27
Jun-80		18.0	25	63.0	26	24
Jul-80		19.0	26	56.0	25	24
Aug-80		17.0	23	52.0	23	21
Sep-80		17.0	27	50.0	24	23
Oct-80		18.0	26	44.9	25	24
Nov-80		18.7	24	45.5	25	
Dec-80		18.7	24	45.8		25
Jan-81		19.8	25	52.1	28	27
Feb-81		19.7	26	54.6	27	27
Mar-81		17.1	24	50.9	23	24
Apr-81		19.1	25	53.2	25	25
May-81		18.2	24	52.1	25	23
Jun-81		19.0	26	55.7	27	26
Jul-81		19.0	25	53.0	25	25
Aug-81		18.5	25	50.5	25	25
Nov-81		17.5	23	42.5	23	24
Dec-81		19.0	24	44.5	24	24
Jan-82		20.0	25	51.0	26	25
Feb-82		20.5	26	52.5	27	27
Mar-82		20.5	26	52.5	27	27
Apr-82		26.0	31	50.0	25	24
May-82		20.5	27	52.0	27	25
Jun-82		19.5	21	51.0	25	23
Jul-82		19.5	26	50.5	26	25
Aug-82		19.5	26	45.0	26	25
Oct-82		19.8	26	51.5	27	26
Nov-82		19.0	25	52.0	26	25
Dec-82		18.0	24	46.0	25	23
Jan-83		14.0	24	49.0	25	25
Feb-83		20.5	26	49.0	25	25
Mar-83		18.0	25	49.0	27	25
Apr-83		19.5	27	48.0	27	22
May-83		20.5	27	53.5	28	26
Jun-83		19.0	25	52.0	26	23
Jul-83		18.0	23	51.0	24	24
Aug-83		20.0	27	58.0	27	26
Sep-83		20.0	25	56.0	26	25
Oct-83		21.2	26	54.5	28	27
Nov-83		20.5	26	53.2	28	27
Dec-83		20.0	25	56.0	27	26
Jan-84		21	28	64	35	29
Feb-84		22	28	64.5	29.5	28.5
Mar-84		18	26	52	28	27
Apr-84		17.5	25.0	50	25	24
May-84		20.8	30.2	56	27.0	19.2
Jun-84		20.0	27.6	58	27	25.2

	Yahara River	Mendota	Monona	Wingra	Waubesa	Kegonsa
Jul-84		19	26	50	26.5	25
Aug-84		19	26	50	26	24.5
Sep-84		20.0	24	49	26	25
Oct-84		20.0	26	53	28	27
Nov-84		19	24	44.5	28	23
Dec-84		20	26	55	26.5	26
Jan-85		19.5	26	44	28	30
Feb-85		21	27	45	30	29
Mar-85		20	27	50	30.5	25
Apr-85		20	30	69	27	25
May-85		20	27	58	28	27
Jun-85		21.5	26.5	63	28.0	27.0
Jul-85		21	32	64	28	27
Aug-85		21	28	64	28	29
Sep-85		22	28	65	27	28
Oct-85		20	26	58	27	26
Nov-85		21	29	53	29	27
Dec-85		20	26	41	27	26
Jan-86		24	28	62	30	29
Feb-86		24	27	60	30	31
Mar-86		23	28	60	31	33
Apr-86		22	26	50	21	22
May-86		23	29	62	29	28
Jun-86		23.5	32.5	62	30.5	28.5
Jul-86		22.0	30	43	32.8	27.6
Aug-86		21	28.4	63.2	30	26.4
Sep-86		21	29	64		30
Oct-86		23.4	29.2	56	31.4	28.4
Nov-86		22.2	29.2	54.4	29.4	29.2
Dec-86		19.0	29.4	55.0	30.2	31.4
Jan-87		21.6	27.8	57.0	29.2	30.2
Feb-87		24.5	31	64	32	31
Mar-87		22.9	27.3	40.0	29.9	29.3
Apr-87		23.7	29.7	57.8	30.3	30.5
May-87		24.9	28.3	54.9	32.5	32.5
Jun-87		25.2	29.2	58.0	28.9	28.8
Jul-87		22	28.1	58.7	28.8	28.1
Aug-87		23	31	61	30	30
Sep-87		23.2	29.4	58.4	29.4	29.4
Oct-87		24	31	58	28	31
Nov-87		28	30	57	33	31
Dec-87		25.1	29.2	54.6	31.3	35.3
Jan-88		25.2	32	57.6	29.2	31
Feb-88		28.6	30.6	54.4	32.2	27.6
Mar-88		26.7	32.3	69.4	33.8	32.3
Apr-88		24.5	34.3	64.2	31.0	26.1
May-88		24.3	33.8	67.4	29.8	28
Jun-88		26.5	36.4	71.5	32.9	31.9
Jul-88		25.3	33.6	73.8	32.1	30.2

	Yahara River	Mendota	Monona	Wingra	Waubesa	Kegonsa
Aug-88		25.9	35.8	75.8	34.5	31.3
Sep-88		27.5	37.5	79.0	35.9	33.5
Oct-88		26.2	35.2	76.2	34.0	33.0
Nov-88		23.8	32.2	74.3	30.8	30.0
Dec-88		23.6	32.6	67.3	30.6	30.8
Jan-89		26.4	36.2	76.2	36.8	35.2
Feb-89		26.4	38.2	76.4	37.2	37.8
Mar-89		30.2	39.4	83.2	36.2	35.4
Apr-89		24.6	37.8	87	36.8	33.4
May-89		27.6	39.4	84	37.4	33.8
Jun-89		27.2	38.4	85.0	54.2	2.6
Jul-89		27.4	38.2	89.0	38.2	35.0
Aug-89		22.6	35.8	82.6	31.8	31.8
Sep-89		23.6	33	80.4	32	29.6
Oct-89		25.8	39.2	80.5	36.6	34.8
Nov-89		27.1	37.9	77.0	36.6	36.1
Dec-89		29.3	37.5	86.3	38.1	37.1
Jan-90		27.6	40.0	98.5	39.8	37.8
Feb-90		28.2	42.1	92.9	43.0	37.3
Mar-90		29.1	43.7	91.8	42.2	38.4
Apr-90		26.9	38.3	78.4	38.3	34.0
May-90		27.9	40.2	82.8	37.8	36.0
Jun-90		29.5	39.1	77.2	37.2	35.1
Jul-90		28.2	32.0	73.6	38.3	35.1
Aug-90		25.2	36.1	72.4	36.8	34.4
Sep-90		27.5	36.9	72.6	26.9	36.5
Nov-90		26.2	31.4	96.5	38.3	30.7
Dec-90		26.7	32.5	110.6	36.1	31.3
Jan-91		30.0	35.4	96.1	40.7	40.3
Feb-91		31.7	38.2	110.3	38.6	37.3
Mar-91		23.3	38.7	70.4		
Apr-91		28.0	45.4	72.2	39.5	34.3
May-91		30.6	42.2	72.0	39.6	37.1
Jun-91		31.1	39.1	74.8	40.5	37.4
Jul-91		29.1	37.3	72.1	33.7	35.2
Aug-91		29.7	43.2	99.2	41.3	36.8
Sep-91		30.5	42.2	66.2	39.6	40.5
Oct-91		31.3	40.2	63.6	39.8	37.7
Nov-91		29.9	41.4	58.2	38.3	36.9
Dec-91		29.0	37.5	56.1	36.1	34.4
Jan-92		28.9	38.3	62.9	38.4	38.2
Feb-92		30.8	43.2	56.5	40.3	38.0
Mar-92		28.5	36.5	63.1	36.9	34.9
Apr-92		29.7	40.7	67.9	38.4	35.3
May-92		28.6	39.3	70.4	39.1	34.7
Jun-92		28.6	39.5	72.9	38.6	35.4
Jul-92		32.9	42.5	77.8		39.6
Aug-92		32.1	41.2	61.5		38.6
Sep-92		31.9	40.5	70.8		38.7

	Yahara River	Mendota	Monona	Wingra	Waubesa	Kegonsa
Oct-92		30.6	41.3	62.5		38.1
Nov-92		31.4	39.4	67.3		39.5
Dec-92		31.7	38.8	59.9	38.1	37.5
Feb-93		31.8	41.3	73.8	43.3	39.7
Mar-93		27.2	37	73.8	37.8	34.3
Jul-93		31.4	41.3	67.1	41.2	39.2
Oct-93		32.2	37.7	52.3	37.7	37.1
Nov-93		32.0	36.8	60.0	37.5	36.9
Dec-93		32.8	38.7	67.3	39.2	38.8
Feb-94		31.8	39.3	64.5	39.1	38.5
Mar-94		33.7	40.8	78.8	41.8	40.5
Jun-94	38.3	33.4	40.4	82.0	39.7	38.2
Jul-94	36.4	33.3	39.3	80.1	39.2	37.9
Aug-94	39.7	34.2	41.3	82.4	39.9	38.0
Sep-94	38.6	31.9	39.0		39.0	37.1
Oct-94	38.9	31.7	38.8	68.8	38.4	37.0
Nov-94	37.0	30.9	36.6	69.5	37.5	36.7
Dec-94	38.7	31.1	38.3	75.4	39.1	37.3
Jan-95	38.3	31.4	38.3	70.9	38.8	38.6
Mar-95	35.3	30.2	37.6	65.7	36.8	36.1
Apr-95	39.1	31.0	39.6	70.8	38.1	35.5
May-95	38.3	31.2	39.5	66.6	38.0	35.3
Jun-95	37.2	31.4	39.2	67.3	39.2	36.3
Jul-95	39.3	32.2	39.9	75.0	39.1	36.9
Aug-95	38.0	32.3	39.5	68.5	39.2	37.8
Sep-95	37.8	32.3	38.7	73.2	39.6	38.5
Oct-95	37.5	31.4	38.6	69.3	38.9	36.9
Jan-96		34.2	42.2	76.4	43.8	41.6
Mar-96		32.4	41.2	74.7	44.1	39.3
Apr-96	38.4	33.6	45.2	88.1	41.3	38.2
May-96	41.0	33.8	46.0	88.9	41.5	39.0
Jun-96	39.5	31.8	39.9	57.2	35.8	34.4
Sep-96	39.6	33.7	41.1		40.7	38.5
Nov-96		35.9	44.4			
Dec-96	46.3	34.5	43.6	73.6	42.8	40.7
Jan-97		35.5	46.7	76.6	45.1	43.3
Feb-97		34.5	44.5	77.4	46.0	42.5
Mar-97	33.1	35.8	46.3	92.7	45.1	38.7
Apr-97	47.3	38	56.9	118.5	47.4	43.7
May-97	32.7	28.9	35.6	88.8	41.0	34.7
Jun-97	37.4	34.1	48.0	102	47.4	41.2
Jul-97	37.3	32.8	41.8	47.4	45.3	37.3
Sep-97	44.3	38.3	49.9	99.7	51.0	48.8
Nov-97		38.3	49.9			
Jan-98				93.4	46.6	49.0
Feb-98				90.9	46.6	46.6
Apr-98				83.9	45.8	41.7
Jun-98	38.2	33.5	43.8	78.0	45.2	42.1
Jul-98	41.5	32.6	42.6	66.4	43.7	42.7

	Yahara River	Mendota	Monona	Wingra	Waubesa	Kegonsa
Sep-98	41.4	32.0	40.1	70.8	41.9	41.2
Oct-98	34.1	35.1	40.4	65.0	39.9	40.6
Dec-98	47.4	32.8	40.5	67.5	41.5	41.2
Feb-99	40.0	32.0	43.2	71.9	45.9	43.9
Mar-99	39.5	33.6	42.0	75.8	42.1	41.5
May-99	38.9	34.0	45.8	81.2	41.8	38.8
Jul-99	37.3	32.6	40.5	76.4	39.9	36.9
Aug-99	39.1	33.1	41.0	76.5	42.0	38.5
Sep-99	37.9	33.7	42.2	79.8	41.9	39.6
Oct-99	37.5	34.2	42.8	73.4	42.0	39.7
Dec-99	38.5	33.9	42.2	75.0	44.5	40.9
Jan-00		35.6		81.3	44.9	43.1
Feb-00	40.2	27.4	41.3	64.7	40.4	40.2
Apr-00		34.0	45.3	81.4	43.1	38.9
May-00	38.5	33.1	45.1	77.0	41.7	39.1
Jun-00	36.9	30.4	39.0	59.4	38.8	36.3
Jul-00	34.2	31.0	37.5	59.9	38.1	36.3
Aug-00	37.1	30.3	36.9	60.4	37.5	36.3
Sep-00	36.6	30.7	36.3	60.6	38.2	37.1
Oct-00	37.3	34.1	41.4	64.2	41.3	40.8
Nov-00	37.4	34.6	42.1	67.2	38.3	40.9
Jan-01		36.4	42.2	74.3	44.1	
Feb-01				81.0	47.0	45.6
Mar-01	28.9	34.5	44.0	83.7	47.3	42.4
Apr-01	38.5	31.8	45.3	94.0	42.9	38.9
May-01	40.6	36.5	46.6	95.1	46.9	41.1
Jun-01	38.9	36.0	45.5	92.1	46.7	41.3
Jul-01	40.7	36.6	45.1	90.5	47.9	43.4
Oct-01	38.1	35.1	40.7	68.6	44.1	42.7
Nov-01	39.7	35.0	43.0	69.2	45.4	43.1
Dec-01	40.1	35.0	43.3	69.7	45.0	42.9
Jan-02	40.7	34.3	43.8	75.7	47.4	45.2
Feb-02	48.0	36.7	43.4	68.5	45.0	43.5
Mar-02	40.5	35.2	47.5	80.8	44.9	42.7
Apr-02	43.6	36.1	46.9	81.8	46.1	41.9
May-02	37.1	35.3	46.3	82.3	46.2	42.8
Jun-02	42.9	35.4	45.1	74.6	45.7	43.1
Jul-02	41.8	36.0	45.8	78.2	46.9	44.7
Aug-02	38.6	36.2	46.0	84.2	47.2	45.1
Sep-02	41.9	36.5	46.8	84.2	47.2	45.5
Oct-02	39.0	36.6	43.1	82.8	43.9	42.3
Nov-02	39.6	37.0	46.7	41.9	44.1	46.5
Dec-02	39.2	37.6	47.2	90.7	45.4	45.1
Jan-03	41.6	37.3	46.9	85.7	46.9	44.1
Feb-03			46.9	92.2	47.4	48.1
Mar-03	56.4		47.6	81.2	44.0	39.2
Apr-03	39.8	38.2	50.7	89.3	44.6	46.0
May-03	38.3	37.5	46.8	90.2	44.6	45.3
Jun-03	41.0	38.8	47.5	94.2	46.1	47.0

	Yahara River	Mendota	Monona	Wingra	Waubesa	Kegonsa
Jul-03	40.5	35.8	47.6	89.3	45.5	42.3
Aug-03	40.4	39.5	48.6	94.9	47.7	43.3
Sep-03	39.8	39.4	50.9	96.6	46.9	43.5
Oct-03	38.8	38.9	47.2	88.3	46.8	43.8
Nov-03	27.0	34.7	45.0	77.5	44.5	43.5
Dec-03	43.1	35.0	43.6	79.2	46.3	44.9
Jan-04		38.6	47.5	84.7	47.2	46.4
Feb-04		41.0	47.4	92.8	48.5	47.6
Mar-04	44.5	38.9	48.7	90.4	46.3	41.8
Apr-04	46.2	36.6	48.3	93.0	46.6	43.2
May-04	41.2	39.2	57.3	94.1	46.7	43.1
Jun-04	39.3	34.0	43.6	68.3	42.6	39.7
Jul-04	41.0	36.5	46.0	66.3	41.8	43.3
Aug-04	40.4	34.1	41.5	67.8	41.7	40.8
Sep-04	40.2	34.2	41.6	68.4	41.5	40.8
Oct-04	41.2	34.7	42.1	69.3	42.6	41.8
Nov-04	40.2	38.4	46.8	70.9	42.6	45.5
Dec-04	40.7	35.5	44.4	69.4	43.5	42.4
Jan-05		38.1	46.2	81.7	49.6	46.7
Feb-05	71.7	34.8	47.8	90.0	53.6	46.5
Mar-05	48.1	35.3	48.7	98.6	52.3	45.7
Apr-05	40.4	36.5	51.5	106	46.4	41.2
May-05	40.1	36.2	50.8	111	47.2	41.9
Jun-05	40.2	37.0	52.7	107	49.3	43.3
Jul-05	40.1	38.0	55.5	107	53.2	45.6
Aug-05	39.5	40.2	53.6	111	54.0	44.6
Sep-05	39.1	36.9	53.3	111	50.4	45.4
Oct-05	41.6	40.0	53.8	112	55.3	48.6
Nov-05	45.7	38.4	53.5	108	52.6	48.3
Dec-05	42.8	38.7	59.1	115	53.9	50.6
Jan-06	41.5	37.7	50.7	108	53.2	49.1
Feb-06			54.8	105	52.9	49.1
Mar-06	44.3	38.3	67.5	104	50.7	46.0
May-06	43.5	36.9	52.1	88.7	51.6	46.1
Jun-06	44.0	39.9	52.5	90.0	52.4	47.5
Jul-06	43.7	40.8	52.0	92.0	52.2	47.9
Aug-06	42.9	40.8	51.6	85.5	51.8	47.7
Sep-06	42.3	39.9	50.3	71.5	48.0	45.9
Oct-06	41.2	37.8	50.3	72.3	48.4	45.5
Nov-06	41.4	37.8	48.9	73.0	49.1	46.4
Dec-06	40.4	36.4	47.9	73.0	48.6	46.3
Jan-07	42.8	38.7	50.3	77.3	51.4	47.3
Feb-07	86.8	40.5	53.1	83.6	58.7	50.4
Mar-07	41.7	37.7	52.0	73.0	53.5	48.7
Apr-07	44.2	40.4	53.7	83.9	50.3	44.7
Jun-07	39.7	38.6	52.2	88.5	52.4	47.7
Jul-07	41.7	41.8	52.5	92.1	53.1	51.5
Sep-07	44.3	36.6	51.1	62.5	50.4	48.0
Oct-07	42.0	37.7	47.4	68.8	47.6	46.4

	Yahara River	Mendota	Monona	Wingra	Waubesa	Kegonsa
Nov-07			46.5	74.1	48.5	47.0
Jan-08				74.6	56.3	53.9
Feb-08	52.3	43.6		89.1	55.8	53.1
Mar-08	69.9	41.1	61.1	94.9	61.6	53.5
Apr-08	48.0	39.3	55.6	81.7	57.3	52.4
May-08	46.4	43.5	60.6	99.3	59.4	55.4
Jun-08	17.0	42.2	53.5	80.4	54.8	54.3
Jul-08	30.6	39.5	49.7	76.1	49.9	47.2
Aug-08	40.3	39.5	51.4	80.3	52.6	51.6
Sep-08	40.5	41.8	53.2	85.1	53.7	53.2
Oct-08	40.3	40.2	52.5	76.9	52.2	51.7
Nov-08	42.2	41.8	53.4	89.1	54.0	53.0
Dec-08	40.7	41.4	52.9	85.5	55.1	54.2
Jan-09		45.9	52.2	102	45.0	55.2
Feb-09	42.6	38.9	55.0	57.3	54.2	53.2
Mar-09	37.3	39.2	57.1	87.6	52.9	46.4
Apr-09	44.5	43.5	60.6	112	56.5	51.3
May-09	43.4	44.9	57.9	106	58.5	56.2
Jun-09	39.7	43.8	55.0	94.1	55.5	50.3
Jul-09	39.7	43.3	53.3		54.3	55.7
Aug-09	40.4	43.7	56.6		56.5	56.8
Sep-09	40.5	45.4	56.7		57.3	53.9
Oct-09	45.2	44.2	47.3		52.5	50.3
Nov-09	45.2	46.1	51.3	88.6	56.9	50.9
Dec-09	55.3	45.4	56.5	90.2	53.8	57.2
Jan-10	54.4	44.5	53.6	87.6	56.8	53.4
Feb-10	46.4	47.8	54.6	108	60.6	57.4
Mar-10	37.4	29.6	56.8	57.2	57.7	56.7
Apr-10	44.6	45.4	59.5	91.3	55.0	52.3
May-10	44.0	46.5	61.2	99.2	58.4	54.5
Jun-10	40.6	43.8	54.1	85.9	55.1	53.7
Jul-10	45.0	44.3	54.0	82.5	54.7	55.3
Aug-10	39.9	42.0	56.1	72.8	56.1	53.8
Sep-10	39.4	42.9	56.9	66.7	55.5	54.4
Oct-10	41.8	44.3	52.6	67.1	53.1	55.0
Nov-10	42.7	43.8	55.3	71.5	55.9	54.5
Dec-10	43.3			76.7	56.7	56.0
Jan-11		48.1	53.5	91.6	57.5	57.3
Feb-11	59.3	46.4	53.5	87.7	62.5	56.0
Mar-11	50.6	44.9	54.1	93.0	65.1	54.8
Apr-11	44.9	46.4	65.8	108	55.9	52.8
May-11	41.5	43.2	62.1	109	60.9	52.5
Jun-11	42.2	46.5	61.8	111	58.0	50.5
Jul-11	39.2	44.4	59.7	117	62.7	<4.0
Aug-11	40.2	44.6	62.6	116	63.3	56.6
Sep-11	38.4	44.5	61.0	115	62.0	57.4
Oct-11	40.1	44.2	61.8	110	62.6	59.3
Nov-11	41.0	44.3	61.6	102	61.9	58.3
Dec-11	41.2	43.4	59.0	132	60.2	57.5

	Yahara River	Mendota	Monona	Wingra	Waubesa	Kegonsa
Jan-12	40.9	45.2	61.5	106	61.8	59.9
Feb-12	45.3	43.4	64.0	106	62.2	61.2
Mar-12	46.6	46.4	61.2	101	61.7	
Apr-12	46.2	48.2	69.0	118	65.3	59.6
May-12	42.7	45.0	65.2	115	63.8	58.0
Jun-12	43.0	46.6	66.9			59.2
Aug-12	42.7	49.5	69.7	127		63.4
Sep-12	41.2	47.3	68.6	125		
Oct-12	45.2	48.0	67.4	116		62.8
Nov-12	42.5	48.0	64.8	116		62.4
Dec-12	44.6	47.1	65.2	107	66.9	64.2
Feb-13	51.9	47.3	71.1	116	72.1	66.1
Mar-13	27.9	54.1	78.3	123	78.8	71.7
May-13	49.8	48.8	78.6	124	72.1	62.0
Jun-13	48.2	51.9	71.3	119	72.1	65.4
Jul-13	46.4	46.2	65.2	97.5	64.0	60.2
Aug-13	46.3	46.8	63.1	97.7	65.1	61.9
Sep-13	44.3	52.1	65.4	103	65.8	63.2
Oct-13	42.9	49.2	68.7	106	68.6	64.5
Dec-13	45.0	48.3	67.4	106	68.8	65.9
Jan-14				117	73.8	
Feb-14			68.1	117	78.6	72.6
Mar-14	34.2	47.8	70.2	111	76.5	71.2
Apr-14	51.9	53.4	76.9	119	70.2	62.1
Jun-14	42.9	48.2	68.4	107	70.2	63.1
Jul-14	48.8	49.2	69.5	111	69.8	64.9
Aug-14	46.7	48.9	66.3	108	68.8	64.5
Sep-14	47.2	49.2	66.3	108	69.6	65.1
Oct-14	47.0	49.5	69.4	98.3	67.7	65.5
Dec-14	47.6	49.9	67.3	109	72.0	68.2
Jan-15	45.8		67.0	103	72.3	70.2
Feb-15			68.8	108	73.2	70.8
Mar-15				102		
Apr-15	50.3	51.0	73.6	102	70.1	62.0
May-15				105		
Jun-15	47.8	49.8	71.1	108	68.9	62.2
Jul-15	47.6	52.4	65.1	105		62.0
Aug-15	50.4	51.5	68.3	103	71.2	64.9
Sep-15	45.8	48.8	67.8	94.5	68.8	64.2
Oct-15	46.4	49.5	67.0	90.8	68.1	65.4
Feb-16	47.2	45.7	64.6	90.0	70.0	66.7
Mar-16	54.5	48.9	69.4	99.7	65.5	59.8
Apr-16	53.1	53.0	71.2	108	72.1	61.4
Jun-16	46.8	47.5	67.1	104	69.2	62.1
Jul-16	43.1	48.6	68.1	98.8	70.5	60.8
Aug-16	45.3	52.0	68.3	94.2	70.9	65.8
Sep-16	39.4	49.1	65.2	80.2	64.2	61.3
Oct-16	46.0	48.5	61.6	80.7	65.1	63.8
Dec-16	43.3	45.1	58.9	69.3	62.6	60.4

	Yahara River	Mendota	Monona	Wingra	Waubesa	Kegonsa
Jan-17		49.9	58.9	86.1	70.4	66.6
Mar-17	56.9	48.9	64.5	131	76.3	62.3
Apr-17	43.9	51.1	76.1	137	75.8	61.2
May-17	45.9	51.6	71.3	135	68.1	64.0
Jun-17	40.3	50.1	70.7	130	69.2	60.1
Jul-17	38.6	46.7	65.4	89.7	63.5	60.8
Aug-17	43.1		64.8	79.8	63.6	60.4
Oct-17	43.4	51.0	64.4	93.5	68.1	65.6
Dec-17	41.9	49.5	68.2	99.7	67.1	64.8
Jan-18	47.7	54.4	66.5	97.5	68.9	67.9
Feb-18	37.0	50.6	67.1	109	71.5	62.6
Apr-18	46.9	52.1	70.2	110	63.5	56.5
May-18		51.4	70.7	108	70.4	63.2
Jun-18	43.1	49.8	64.6	76.8	57.7	56.0
Jul-18	44.7	51.4	63.7	84.5	61.0	57.1
Aug-18	32.4	45.9	58.6	63.9	59.5	56.9
Sep-18		47.2	57.2	55.5	59.9	53.7
Nov-18	46.4	49.0	59.6	74.8	61.1	55.7
Dec-18	45.4	47.6	57.3	78.7	61.8	57.9
Feb-19		50.6	64.3	106	71.9	62.9
Apr-19	53.6	50.9	79.7	135	71.8	63.5
Jun-19	42.8	49.9	67.8	126	73.2	61.9
Aug-19	40.5	49.7		112	67.8	64.1
Sep-19	42.9	49.8		99.7	67.1	65.5
Oct-19	42.4	47.5		77.6	51.1	60.0
Dec-19	45.2	52.2	65.1	95.7	66.7	62.6

APPENDIX 5: UNIVERSITY BAY AND STARKWEATHER CREEKS CHLORIDE (MG/L) DATA

TABLE 4: Urban tributary chloride concentrations. **Red font** indicates an exceedance of the acute or chronic toxicity criterion.

	University Bay Creek	Starkweather Creek @ Hwy 51	Starkweather Creek @ Zeier Rd	Starkweather Creek @ Anderson St	Starkweather Creek @ Ivy St	Starkweather Creek @ Fair Oaks Ave	Starkweather Creek @ Atwood Ave
Jan-08	115						
Feb-08	***734***			114.9		190	
Apr-08	143						
May-08	99.1		109				
Jun-08			34.5	15.7		15.3	
Jul-08			60.9	39.0	76.0	40.3	
Aug-08	137		99.7	56.0	104	58.5	
Oct-08	110		92.1	55.2	116	58.8	
Nov-08			113	58.7	***423***	81.3	
Dec-08	***835***		***427***	372	***765***	***428***	
Jan-09	***409***		106	73.3	161	96.8	
Feb-09	***588***		160	77.9	235	106	
Mar-09	159		118	76.8	181	84.1	123
Apr-09	136		64.1	68.5	130	95.4	117
May-09	121						
Jun-09	127		127	122	158	70.8	105
Jul-09	122		113	58.0	154	69.4	68.6
Aug-09	77.0		112	58.8	139	62.1	
Sep-09	78.3		101	60.5	140	66.4	
Oct-09	47.1		108	57.3	148	68.6	95.2
Nov-09	73.2		116	64.3	190	74.7	129
Jan-10	119		151	95.3	204	134	168
Feb-10	***471***		275	75.8	***416***	129	192
Mar-10	215		137	70.4	189	96.7	123
Apr-10	141		131	64.6	188	87.7	130
May-10	108						
Jun-10			121	47.4	144	57.3	66.5
Jul-10	116		54	20.9	81.6	23.1	30.3
Aug-10				50.1	110	52.2	
Sep-10	105		109	58.6	169	70.3	60.6
Oct-10	120		136	70.5	172	93.8	
Nov-10	154		109	64.9	130	77.3	100
Dec-10	129		133	74.2	179	88.3	133
Jan-11	181		163	72.2	217	91.8	
Feb-11	***1930***		***452***	206	***684***	325	***519***
Mar-11	89.9		253	133	329	167	207
Apr-11	115						
May-11			134	74.2	182	93.4	118
Jun-11	94		145	70.6	155	78.3	
Jul-11	109		127	73.8	126	85.7	98.6

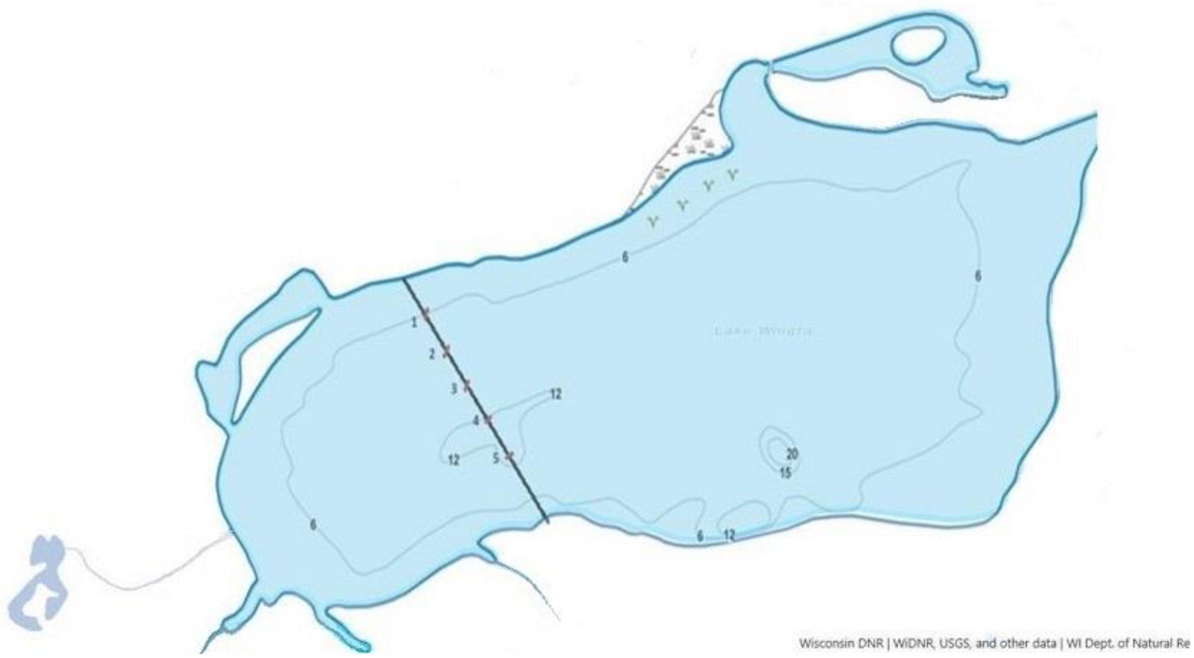
	University Bay Creek	Starkweather Creek @ Hwy 51	Starkweather Creek @ Zeier Rd	Starkweather Creek @ Anderson St	Starkweather Creek @ Ivy St	Starkweather Creek @ Fair Oaks Ave	Starkweather Creek @ Atwood Ave
Aug-11	178		115	65.4	119	66.5	
Sep-11	113		118	74.4	136	81.1	110
Oct-11			109	72.4	131	80.8	
Nov-11			110	68.9	140	82.6	102
Dec-11	107		108	66.3	130	75.3	96.2
Jan-12	213		130	70.3	208	94.3	136
Feb-12	120		168	81.0	243	112	162
Mar-12	152		130	76.2	175	105	124
Apr-12	109						
May-12	90.5						
Jun-12			150	77.6	186	88	
Jul-12			120	75.8		81	
Aug-12	155		113	77.8	111	78	
Sep-12	159		114	74.0	121	80	
Oct-12	68.9		119	70.7	136	70	90.7
Nov-12	219						
Dec-12	108		144	78.6	156	95	
Feb-13	261		***866***	169.0			
Mar-13	***815***		289	137.0	345	189	
Apr-13			146	78.8	187	106	
Jun-13	190		159	68.2		91	
Jul-13	206		141	54.2	110	62	59.5
Aug-13	269		152	78.5	157	89	
Sep-13	88.4		145	75.8	123	84	
Oct-13	70.2		133	85.5	162	97	113
Dec-13	***1006***		158	102	***400***	92	166
Feb-14	***555***		192	394			***439***
Apr-14	234						
Jun-14			136	70.8	170	92	
Jul-14			150	78.6	161	105	
Aug-14			139	73.3	161	89	
Sep-14	122		157	77.4	177		
Dec-14	189		231	176	***464***	238	***434***
Jan-15	266	102	136	105	***440***		
Apr-15	233	90.6	136	85.8	183	108	
Jun-15	224	91.1	137	83.0	170	99	
Jul-15	71	79.9	105	66.1	119	78	75.0
Aug-15	101	93.2	124	81.9	170	95	
Sep-15	159	47.9	73.3	27.1	49	27	30.6
Oct-15	67	89.1	137	73.8	143		94.5
Feb-16	203	97.3	226	96.0	258	143	180
Jun-16		102	128	82.6	172	94	109
Jul-16	94	85.2	109	51.8	131	59	
Aug-16		73.9	127	52.5	141		
Sep-16		61.7	118	40.6	121	49	57.9
Oct-16		85.1	132	103	191	92	118
Dec-16	70.2						
Feb-17		143	174		241	138	172

	University Bay Creek	Starkweather Creek @ Hwy 51	Starkweather Creek @ Zeier Rd	Starkweather Creek @ Anderson St	Starkweather Creek @ Ivy St	Starkweather Creek @ Fair Oaks Ave	Starkweather Creek @ Atwood Ave
Mar-17		205	166	184	272	205	229
May-17	115						
Jun-17	135	111.6	107	73.8	176	156	108
Jul-17		84.4	66.7	37.4	106	34.3	47.7
Aug-17		90.1	100	66.5	161	68.3	90.9
Oct-17	143	114.5	120	84.6	181	99	
Dec-17	178	98.6	128	86.3	187	94.4	133
Jan-18	122	112	143	93.1	191		
Feb-18	129	163	59.8	112	119		144
Apr-18	167						
May-18		99.3	240	93.8			
Jun-18		118	135	78.7			
Sep-18		114	118	73.8			
Nov-18	164	120	124	87.5	203	108	
Dec-18	153	120	133	96.1	204	108	151
Jun-19	138	126	109	95.0	208		
Sep-19	180	130	106	83.3	175		113
Oct-19			107	86.7	149		107
Dec-19			119	95.9	228	118	

APPENDIX 6: LAKE WINGRA WINTER CHLORIDE PROFILE 2014

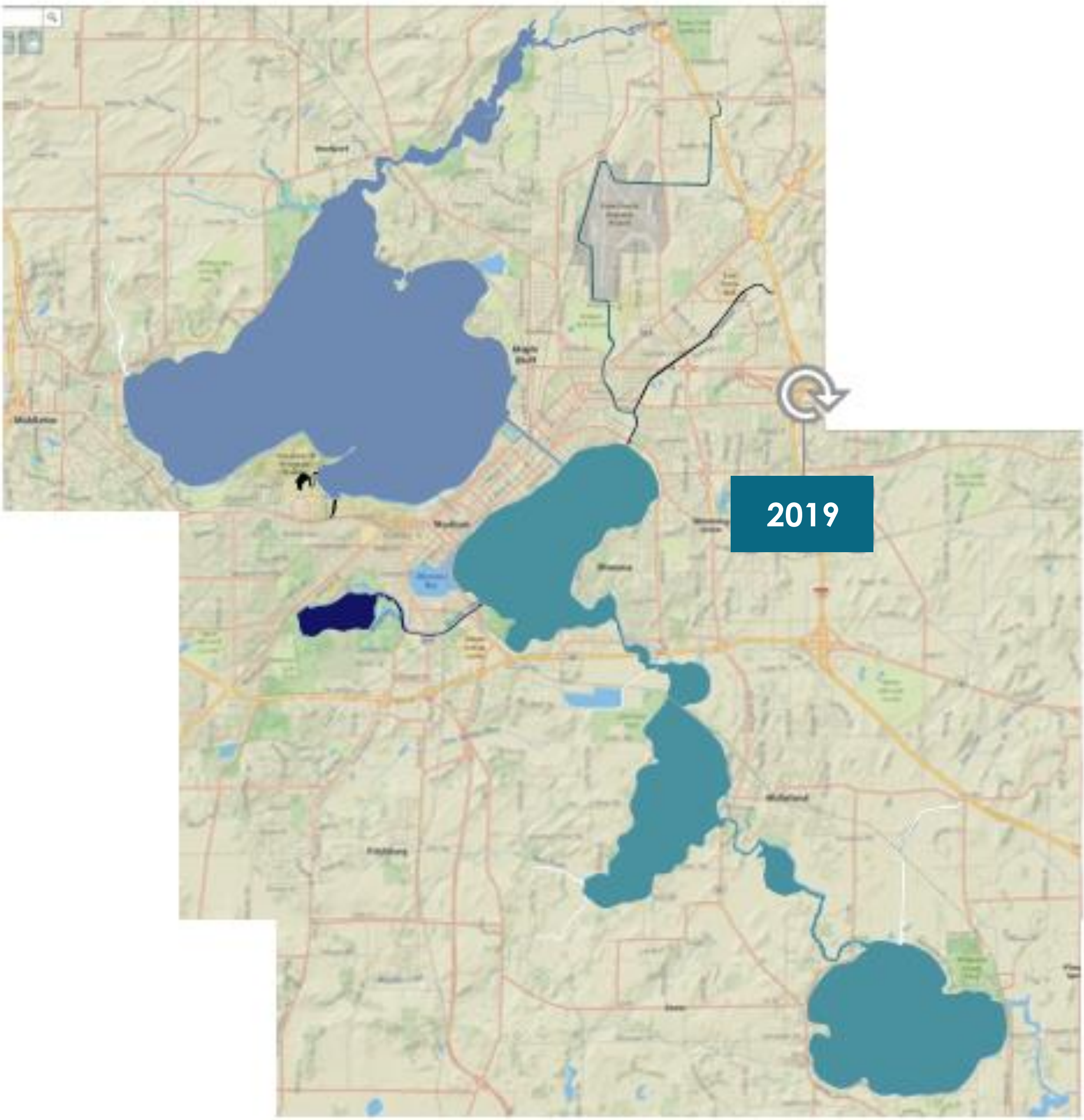
In February and March of 2014, Lake Wingra was sampled to produce a chloride profile. A transect was chosen to include some of the deepest water in the lake. Five sample points, approximately 100 yards apart with a starting point at the end of Knickerbocker Street and proceeding south east were used (see Figure 5). Conductivity was recorded at two-foot intervals for each site on four occasions. Six chloride samples were also taken with a Van Dorn sampler, four from a depth of two feet and two from a depth of ten feet. Ionic variability was too high to reliably correlate conductivity to chloride concentration. Of particular interest, though, is the chloride concentration in the 10+ foot interval: 527 mg/L and 406 mg/L on March 13, and March 20 respectively. These levels exceed the Wisconsin chronic toxicity criterion for chloride (395 mg/L).

FIGURE 9: Wingra chloride profile sample points.



APPENDIX 7: TIME SERIES GRAPH OF YAHARA CHLORIDE CONCENTRATIONS

FIGURE 10. Times series of changes in chloride concentration in Yahara Lakes. Darker colors indicate a higher concentration of chloride. From 1940 to present, waterbodies on the map gradually get more concentrated with chlorides (darker blue). For full animation, see the Public Health Madison & Dane County website.



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