City of Madison Road Salt Report – 2003-2004

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Summary

Winter road maintenance in Madison is critical and the application of road salt is an important tool in the maintenance process. However, the overuse of road salt can negatively impact the environment. For this reason, the Madison Common Council implemented a plan to reduce the use of road salt in the City of Madison to 50% of the amount used in the winter of 1972-73. In the winter of 2003-04, there was a 3% decrease in road salt applied over 1972-1973, after correcting for the increase in miles of roads maintained. Monitoring of surface and ground water continue to show increasing trends in chloride and sodium levels although the levels are not yet a human health hazard. Storm water monitoring during snowmelt has identified surges of extremely high levels of chloride. These surges have the potential of harming fish and other aquatic organisms as they enter local lakes and rivers. Additional efforts to reduce road salt applications are needed if Madison is going to achieve the goals set in the 1970's. It is also important to expand salt reduction efforts to neighboring communities and private properties in order to reduce the sodium and chloride inputs to surface and groundwater resources.

Historical Background

The City of Madison began recording use of sodium chloride (road salt) as a street deicer in the winter of 1959-60. In 1962, the Madison Common Council requested that the Madison Department of Public Health (MDPH) begin a study of the effects of road salt on surface waters in the Madison area. At that time, the environmental effects of chemical deicers were found to be minimal.

In 1973, the Madison Common Council implemented a plan to reduce the use of road salt in the Lake Wingra watershed to 50% of the amount used in the winter of 1972-73. As part of this plan, the Council renewed MDPH's charge to monitor and analyze the effects of road salt use. In the winter of 1977-78, the 50% salt use reduction objective was extended to include the entire City and MDPH was directed to submit an annual salt report to the Madison Common Council.

Introduction

Road salt is an important tool for winter road maintenance. Madison Streets Division's winter road maintenance program includes plowing, spreading abrasives

(sand), and spreading deicing chemicals (road salt). Madison uses sodium chloride for deicing because it is readily available, inexpensive, and effective. The primary factors considered by Streets personnel when making decisions about winter road maintenance are ice conditions and traffic safety. In 2003-04, the Streets Division was responsible for maintaining 732 street miles of roads and highways in Madison.

The communities surrounding Madison also apply road salt in the process of winter road maintenance. The Dane County Highway Department maintains County roads and highways and contracts with the Wisconsin Department of Transportation for maintenance of the Beltline and interstate highways. Dane County salts an estimated 2700 lane miles (roughly equivalent to 1000 street miles) of county roads and highways. The salted area covered by private applicators is unknown.

Although road salt plays an important role in assuring transportation safety, it also poses a significant environmental health concern. Water from snow and ice melt carries dissolved road salt into lakes and streams through stormwater runoff and into groundwater through water seepage. Because chloride ions from dissolved road salt are not removed from water by chemical or biological processes, all of the chloride applied as road salt is expected to reach surface water or groundwater. Dissolved sodium also moves easily in the environment although some sodium ions will be adsorbed by the soil. At sufficient concentrations, these chemicals may have toxic effects on plants and fish. If these chemicals seep into our deep groundwater reservoirs, our drinking water quality is also at risk. The following report provides the most recent assessment of Madison's road salt use on the environment.

## Monitoring Results

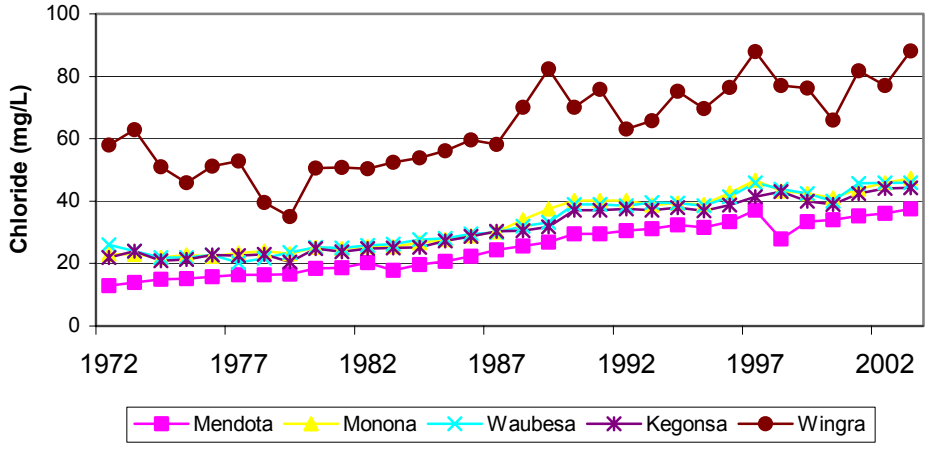
During the winter of 2003-04, 7853 tons of salt and 4909 tons of sand were applied in the process of maintaining 732 miles of Madison streets (Table 1). Because new streets are built every year, measuring progress towards meeting the 50% reduction goal should include the amount of street area maintained. In the winter of 1972-73, 11.1 tons of salt were applied per mile of street maintained. In 2003-04, 10.73 tons of salt per mile of street maintained were applied, representing a 3% decrease. Over the last 10 years, changes in salt application rates have ranged from a 19% reduction in 2001-02 to a 59% increase in 2000-01. The winter of 1984-85 was the last winter that salt use was reduced by 50% or more from 1972-73 rates. The amount of road salt added to the environment by individuals and agencies other than the City of Madison is unknown. Municipalities and agencies in Dane County purchased 36,470 cubic yards (approximately 40,116 tons) of road salt (including the salt portion of sand salt mixtures) for the 2003-04 winter season (Table 2). If all of

this salt were applied during the season, it would be five times the amount applied by the City of Madison. The amount of salt applied to private property, both commercial and residential, may be large. However, Department efforts to collect data on the amount of salt used in these areas have been unsuccessful.

Levels of chloride in Madison's drinking water are lower than the Wisconsin Department of Natural Resources Preventive Action Limit (PAL) of 125 mg/L (Table 3). With the exception of well 27, the wells listed in Table 3 show small annual increases in sodium and chloride levels. Over time, these small increases have added up to significant increases of these chemicals in drinking water. Between 1975 and 2003, chloride in Well No.6 has increased 235%. Chloride in Well No.10 has increased 340% and Well No.17 shows a 347% increase in chloride levels. Sodium has increased less dramatically over this time period. The average sodium levels in our drinking water range from 2.5 to more than 14 mg/L in active wells. However, levels in excess of 20 mg/L have been detected in well 17. The US EPA has set the health-based drinking water guideline at 20 mg/L to protect individuals on sodium-restricted diets (500 mg sodium/day).

Chloride concentrations in Madison springs, fed by shallow groundwater, are two to four times higher than the concentrations found in impacted drinking water wells, which tap the deep groundwater aquifer (Table 4). These levels are consistent with levels observed in previous studies by Edgewood College students and members of the Friends of Lake Wingra.

**Figure 1. Chloride Levels in Madison Lakes**




The long-term trends in chloride and sodium levels in the local surface waters continue to exhibit gradual increases. However, these chloride levels have not yet exceeded Wisconsin Department of Natural Resources (WDNR) standards for chronic or acute toxicity, 395 mg/L and 757 mg/L respectively. This suggests that these surface waters, while impacted by past deicing activities, are not yet at toxic levels (Tables 5 and 8 and

Figure 1). Small water bodies such as Lake Wingra and mid-size lakes such as Lake Monona that drain large urbanized areas are more sensitive to the impacts of road salt than larger Lake Mendota.

Routine monitoring, performed during dry periods, has shown steadily increasing concentrations of these chemicals; however, water analysis of storm water entering the lakes has shown extreme spikes in chloride concentrations. During the winters of 2002-03 and 2003-04, the USGS monitored specific conductance continuously in two locations, the Spring Harbor stormsewer and along Starkweather Creek. In Spring Harbor stormsewer, estimated chloride levels based on specific conductance ranged from 100 to 36,000 mg/L. The estimated total amount of chloride entering the stormsewer at Spring Harbor between January and April was 0.140 metric tons (0.23 tons of salt) in 2003 and 0.190 tons (0.29 tons of salt) in 2004. This stormsewer discharges directly into Lake Mendota. During a snowmelt event in February 2003, estimated chloride concentrations in Spring Harbor near the storm sewer outfall reached 1700 mg/L under the ice and 3300 mg/L near the bottom. With an increasing distance from the outfall, estimated chloride concentrations were diluted to 320 mg/L under ice and 920 mg/L near the bottom (Table 6). Estimated chloride concentrations within the Spring Harbor stormsewer at this time ranged from 19,000 to 20,000 mg/L. Estimated chloride concentrations at the Starkweather Creek monitoring location ranged from about 50 to 1500 mg/L during the winter of 2004 (Table 6).

Data available from the Wisconsin State Climatology Office suggest that winters have become milder since the winter of 1972-1973. The total amount of winter precipitation has decreased during this period; however, none of the recorded totals were significantly different from the mean of

**Figure 2. Total Winter Precipitation, Dane Co. Airport**

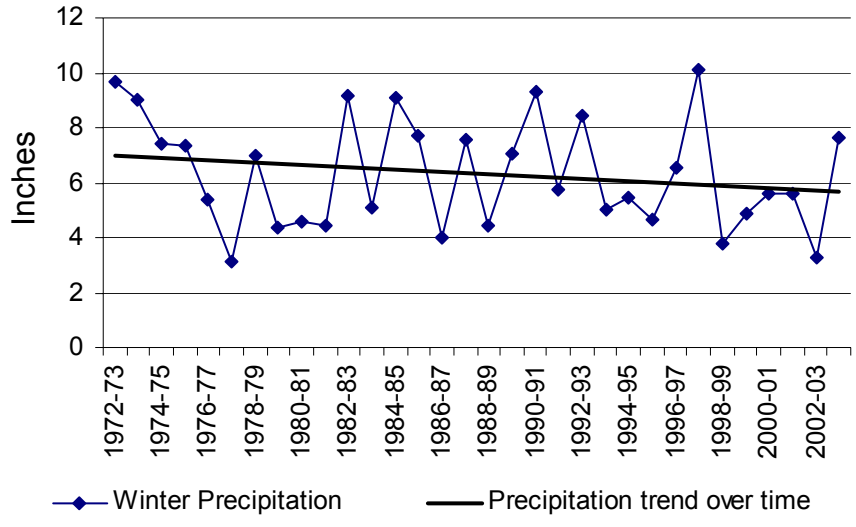
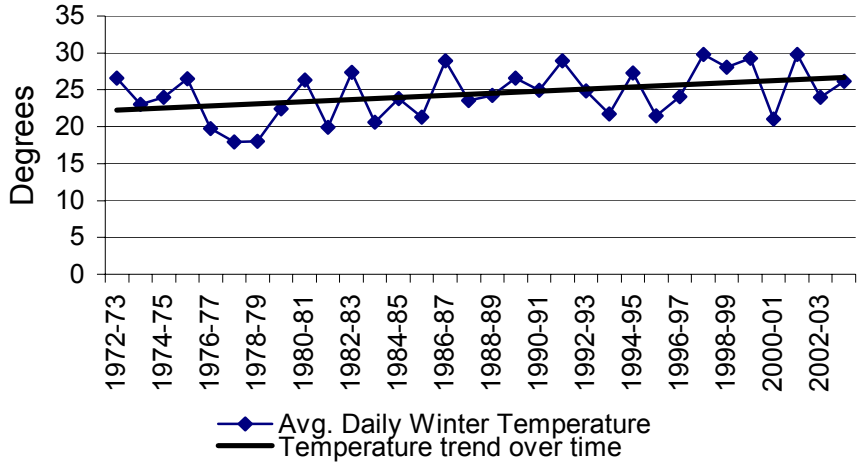


**Figure 3. Average Daily Winter Temperature, Dane Co. Airport**




6.3" of winter precipitation (Figure 2). Winter precipitation is defined as all precipitation received during the months of December through March. Snow and ice are included in this measure after being melted to liquid water. Since 1972-73, the average daily temperature recorded from December through March has increased although not significantly (Figure 3).

Discussion

Although the total amount of salt applied has increased over time, we have also seen an increase in the miles of streets being maintained. Our current measure to account for the quantity of street maintained, street miles, might overestimate the application rate because it does not take into account the number of lanes each street represents. Because there has been a considerable change in the number of multi-lane streets in Madison, this may be significant. However, the number of lane miles maintained is not available at this time. Using the best measure available, tons of salt applied per street mile, and considering the increasing mildness of winters in Madison, the goal set by the Madison Common Council in 1973 is not being achieved.

In addition to Madison street deicing, Madison's water resources are impacted by deicing activities that occur in the communities surrounding the City as well as on private property within the City. Only 30% of the of the total area drained by the Yahara River north of Lake Waubesa lies within the City of Madison. However, efforts to quantify the amount of salt applied in these areas have been mostly unsuccessful. Table 2 shows that agencies maintaining streets and highways around Madison purchased over five times the salt that was applied in Madison. However, there is no information on how much of this road salt was applied during the winter. In the case of private property, there is no data on the amount of deicing salt applied to driveways, sidewalks, and parking lots. Due to the large size and increasing development of

parking lots associated with shopping centers, road salt applications on parking lots may be a significant portion of the total application of road salt in Madison.

Levels of chloride and sodium in Madison groundwater and surface water continue to be within the regulatory limits and are not a human health hazard at this time. The only exception to this statement is the sodium level found in drinking water well #17. As shown in Table 3, the water from this well has exceeded the US EPA guidance value (non-enforceable) for sodium in the past. While the presence of elevated sodium in this well was higher than desired, it is not considered to be a human health hazard and the last two years has shown acceptable levels of sodium in this well.

A pilot study conducted by the USGS and MDPH has measured specific conductance and subsequently estimated chloride concentrations as high as 36,000 mg/L in stormwater runoff discharging directly into Lake Mendota. This translates to 59,000 mg/L of salt, which is 69% higher than the concentration of salt in seawater (Table 7). The receiving water in Lake Mendota as well as Starkweather Creek also exhibited high chloride concentrations during a snowmelt event, exceeding the chronic and acute toxicity levels set by the Wisconsin DNR for chloride. These extreme levels of chloride in storm runoff may exert severe short-term adverse effects on aquatic organisms and biological diversity, particularly in low-dilution aquatic systems. Canadian researchers have estimated that 5 percent of aquatic species would be affected at chloride concentrations of about 210 mg/L, and 10 percent of species would be affected at chloride concentrations of about 240 mg/L. Sensitive algal species are affected at concentrations as low as 10 to 20 mg/L of chloride (Environment Canada, 1999).

High levels of chloride, due to dissolved road salt, in snow and ice melt is toxic to a variety of grasses, flowering plants and trees (terrestrial plants). For this reason, the Salt Institute cautions against the overuse of salt for deicing on sidewalks and driveways. Studies have shown that vegetation along heavily salted roads is negatively impacted by dissolved road salt when it seeps into soils or is splashed directly onto the plant. While these effects are known, the Madison Department of Public Health has not received complaints from owners or managers of properties where grass, flowering plants or trees have been damaged by excessive salt applications. The Department's monitoring effort does not include the measurement of dissolved road salt in soils or on vegetation near streets receiving road salt. Without complaints or monitoring data, this report is unable to assess the impact of road salt on terrestrial plants in Madison.

## Conclusions

The data presented in this report suggest that additional efforts are needed if the City expects to achieve the road salt use goals set in the 1970's. As recently as the winter of 2001-02, the City realized an 18.6% reduction in salt use, which indicates that increased efforts may not need to be dramatic. However, an increased effort is necessary due to the fact that surface water and groundwater monitoring shows increasing levels of chloride and sodium in Madison's drinking water, lakes, and rivers. While levels do not yet pose a human health hazard, salt concentrations in storm water are high enough to potentially cause changes is the aquatic and terrestrial biota favoring halophilic species. In addition to reducing salt use on Madison streets, additional actions to consider include:

- Quantify the street lane miles salted within the City using existing geographic information system (GIS) data and aerial photography. This would be especially useful if the lane miles maintained in 1972-73 could also be estimated.
- Continue to evaluate deicing alternatives.
- Work with communities surrounding Madison to adopt salt reduction plans.
- Provide educational information to private property owners, especially businesses with large parking lots.
- Work to better estimate the total salt used on all property in the City of Madison and other communities in the Yahara River watershed.

References:

Environment Canada, 1999. Priority Substances List Assessment Report. Road Salts Canadian Environmental Protection Agency.

Acknowledgements:

Abdiel Galindo, Madison Department of Public Health, was instrumental in compiling the road salt application and water monitoring data presented in this report. He has also performed a significant amount of the research that laid the foundation of this report.

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Dane County Public Works
Steve Corsi, The US Geological Survey

## Table 1. Madison Street Division Salt/Sand Usage 1972-73 Season to 2003-04

| Year | # Salt Applications | Salt Applied (tons) | Sand Applied (tons) | Streets Maintained (miles) | Salt Applied per Street Mile (tons/mile) | Change from Winter 1972-73 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Total Salt Applied | | Salt Applied per Street Mile | |
| | | | | | | (tons) | (%) | (tons) | (%) |
| 1972-73 | 21 | 5690 | 2990 | 512 | 11.12 | -- | -- | -- | -- |
| 1973-74 | 29 | 3760 | 5220 | 517 | 7.26 | -1930 | -34% | -3.86 | -35% |
| 1974-75 | 34 | 4850 | 4630 | 517 | 9.38 | -840 | -15% | -1.74 | -16% |
| **1975-76** | **27** | **2490** | **5140** | **525** | 4.73 | **-3210** | **-56%** | -6.39 | -57% |
| **1976-77** | **24** | **1520** | **5700** | **529** | 2.87 | **-4170** | **-73%** | -8.25 | -74% |
| **1977-78** | **20** | **2280** | **8930** | **538** | 4.23 | **-3420** | **-60%** | -6.89 | -62% |
| 1978-79 | 27 | 3280 | 8460 | 548 | 5.99 | -2410 | -42% | -5.12 | -46% |
| **1979-80** | **21** | **2680** | **4940** | **558** | 4.81 | **-3010** | **-53%** | -6.31 | -57% |
| **1980-81** | **20** | **1620** | **5800** | **563** | 2.88 | **-4070** | **-72%** | -8.24 | -74% |
| 1981-82 | 24 | 4010 | 7540 | 565 | 7.09 | -1680 | -30% | -4.03 | -36% |
| 1982-83 | 23 | 2890 | 3480 | 568 | 5.09 | -2800 | -49% | -6.03 | -54% |
| 1983-84 | 23 | 4980 | 6180 | 552 | 9.02 | -710 | -13% | -2.10 | -19% |
| 1984-85 | 20 | 2900 | 4260 | 568 | 5.10 | -2790 | -49% | -6.02 | -54% |
| 1985-86 | 30 | 5570 | 8730 | 561 | 9.93 | -120 | -2% | -1.18 | -11% |
| 1986-87 | 16 | 3270 | 3010 | 564 | 5.80 | -2420 | -42% | -5.32 | -48% |
| 1987-88 | 23 | 4490 | 5370 | 571 | 7.87 | -1200 | -21% | -3.25 | -29% |
| 1988-89 | 23 | 4390 | 7060 | 580 | 7.57 | -1300 | -23% | -3.54 | -32% |
| 1989-90 | 23 | 5600 | 5800 | 587 | 9.54 | -90 | -2% | -1.58 | -14% |
| 1990-91 | 24 | 5840 | 5730 | 587 | 9.94 | 150 | 3% | -1.18 | -11% |
| 1991-92 | 20 | 4950 | 3750 | 591 | 8.37 | -740 | -13% | -2.74 | -25% |
| 1992-93 | 31 | 7150 | 4120 | 595 | 12.01 | 1460 | 26% | 0.89 | 8% |
| 1993-94 | 27 | 6820 | 3950 | 621 | 10.99 | 1130 | 20% | -0.13 | -1% |
| 1994-95 | 28 | 5910 | 4200 | 628 | 9.41 | 220 | 4% | -1.70 | -15% |
| 1995-96 | 22 | 8090 | 7030 | 632 | 12.81 | 2400 | 42% | 1.69 | 15% |
| 1996-97 | 35 | 9860 | 6120 | 636 | 15.51 | 4170 | 73% | 4.39 | 39% |
| 1997-98 | 31 | 7450 | 4060 | 643 | 11.59 | 1760 | 31% | 0.47 | 4% |
| 1998-99 | 24 | 6640 | 6840 | 655 | 10.14 | 950 | 17% | -0.97 | -9% |
| 1999-00 | 25 | 7980 | 4700 | 655 | 12.18 | 2290 | 40% | 1.06 | 10% |
| 2000-01 | 28 | 12485 | 7818 | 707 | 17.66 | 6796 | 119% | 6.54 | 59% |
| 2001-02 | 20 | 6423 | 2320 | 710 | 9.05 | 733 | 13% | -2.07 | -19% |
| 2002-03 | 20 | 9010 | 3163 | 731 | 12.33 | 3320 | 58% | 1.21 | 11% |
| 2003-04 | 22 | 7853 | 4909 | 732 | 10.73 | 2163 | 38% | -0.39 | -3% |

## Table 2. Dane County Highway Department & WI DOT Salt Purchases for the 2003-04 Winter Season

| Towns | Salt cu. yd. | Salt-Sand Mix cu. yd. |
|---|---|---|
| Berry | 374.44 | 0 |
| Black Earth | 99 | 0 |
| Blooming Grove | 142 | 0 |
| Blue Mounds | 76 | 0 |
| Bristol | 164.81 | 0 |
| Burke | 689.57 | 0 |
| Christiana | 123.55 | 0 |
| Cross Plains | 408.43 | 0 |
| Dane | 108 | 0 |
| Dunkirk | 77 | 0 |
| Madison | 286.09 | 0 |
| Mazomanie | 32 | 0 |
| Montrose | 184 | 0 |
| Perry | 57.5 | 0 |
| Pleasant Springs | 211.42 | 0 |
| Primrose | 44 | 0 |
| Roxbury | 472.02 | 0 |
| Rutland | 135.5 | 0 |
| Springdale | 155 | 0 |
| Springfield | 330.05 | 0 |
| Vermont | 72 | 0 |
| Windsor | 502.94 | 0 |
| **Cities** | | |
| Monona | 232 | 0 |
| Stoughton | 721.5 | 0 |
| **Villages** | | |
| Black Earth | 43 | 0 |
| Blue Mounds | 78.25 | 0 |
| Cottage Grove | 167.5 | 0 |
| Cross Plains | 100 | 0 |
| Dane | 27 | 0 |
| Maple Bluff | 70 | 0 |
| Mazomanie | 17 | 0 |
| McFarland | 558 | 1 |
| Shorewood Hills | 69 | 5 |
| **Agency** | **Salt cu. yd.** | **Salt-Sand Mix cu. yd.** |
| Federal agencies | 38.5 | 0 |
| State-various | 206 | 0 |
| UW | 572.5 | 0 |
| Mad Metro Sewer Distr | 24 | 2 |
| Wis Heights School Distr | 4.5 | 0 |
| Stoughton School Distr | 38 | 2 |
| Other County Depts. | 355.55 | 6.5 |
| WisDOT Usage | 18,581.50 | 18 |
| County Highway Usage | 9,809.50 | 11 |
| **TOTALS** | **36,458.62 (40,104 tons)** | **45.5 (50 tons)** |

- Treated sand is mixed at a 3:1 ratio, 3 parts sand to 1 part salt.
- One Cubic Yard of Road Salt equals approx 1.1 tons.
- WI Dept. of Transportation maintains interstate and state trunk highways.
- County Highway maintains county trunk highways.
    - Salt usage by municipalities does not reflect their quantity on hand when the season started, purchases from other sources or their season ending inventory, if any (Dawn S. Erickson, Dane Co. Public Works).

## Table 3. Sodium and Chloride History, Selected Madison Water Utility Deep Wells 1975-2003

| | UW 4 | | UW 6 | | UW 10 | | UW 17 | | UW 26 | | UW 27 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year Drilled | 1930 | | 1937 | | 1953 | | 1966 | | 1986 | | 1989 | |
| Well Depth (ft) | 737 | | 750 | | 1005 | | 800 | | 1175 | | 744 (replaced UW 4) | |
| **Year** | **Na** | **Cl** | **Na** | **Cl** | **Na** | **Cl** | **Na** | **Cl** | **Na** | **Cl** | **Na** | **Cl** |
| 1975 | 28 | 52 | 4.6 | 8.2 | 2.6 | 1.0 | 9.0 | 13.0 | | | | |
| 1976 | | | 4.8 | 9.0 | 2.3 | <1.0 | 9.2 | 13.1 | | | | |
| 1977 | | | 5.0 | 8.4 | 2.4 | <1.0 | 11.9 | 16.7 | | | | |
| 1978 | | | 5.3 | 9.5 | 2.5 | 1.6 | 10.0 | 15.1 | | | | |
| 1979 | | | 5.0 | 12.0 | 2.3 | 1.4 | 10.0 | 18.0 | | | | |
| 1980 | 27.0 | | 5.7 | 13.7 | 2.3 | 1.0 | 16.1 | 33.5 | | | | |
| 1981 | 27.0 | | 6.0 | 14.0 | 2.4 | <1.0 | 14.0 | 23.8 | | | | |
| 1982 | 46.0 | 150.0 | 6.5 | 16.0 | 4.0 | <1.0 | 12.4 | 22.9 | | | | |
| 1983 | 48.0 | 115.0 | 6.8 | 17.1 | 2.4 | <1.0 | 14.2 | 24.8 | | | | |
| 1984 | 46.0 | 118.0 | 7.9 | 18.2 | 2.6 | 1.0 | 13.8 | 23.6 | | | | |
| 1985 | 45.0 | 114.0 | 7.0 | 13.0 | 2.8 | 1.0 | 14.0 | 24.0 | | | | |
| 1986 | 45.4 | 121.0 | | | 2.6 | 1.6 | 11.9 | 20.5 | | | | |
| 1987 | 37.3 | 101.0 | 6.2 | 23.8 | 2.5 | 3.6 | 8.6 | 17.0 | | | | |
| 1988 | 41.9 | 108.0 | 8.0 | 22.4 | 2.5 | 2.4 | 12.9 | 27.7 | 1.9 | 1.1 | | |
| 1989 | 46.0 | 114.0 | | | 2.6 | 3.0 | 10.7 | 11.6 | 1.8 | 1.0 | | |
| 1990 | 44.4 | 114.0 | 7.3 | | 2.4 | 1.1 | 13.0 | 28.2 | 1.9 | <0.5 | | |
| 1991 | 46.8 | 96.0 | 6.8 | 19.0 | 2.6 | 1.6 | 20.0 | 46.6 | 2.1 | 1.5 | | |
| 1992 | 47.7 | 115.9 | 6.8 | 21.5 | 2.5 | 1.8 | 15.3 | 36.0 | 2.3 | 1.6 | | |
| 1993 | | | 7.2 | 23.0 | 2.4 | 3.0 | 20.1 | 49.0 | 2.3 | 3.0 | | |
| 1994 | | | 7.6 | 21.9 | 2.5 | 1.5 | 12.8 | 26.3 | 2.4 | 2.1 | 13.6 | 33.0 |
| 1995 | | | 8.0 | 23.0 | 2.0 | 3.0 | 11.0 | 21.0 | 2.0 | 3.0 | 12.0 | 30.0 |
| 1996 | | | 7.8 | 24.6 | 2.5 | 3.6 | 21.0 | 52.8 | 2.6 | 3.5 | 11.0 | 25.9 |
| 1997 | | | 7.7 | 22.7 | 2.5 | 2.3 | 22.0 | 54.4 | 2.8 | 3.7 | 11.0 | 24.8 |
| 1998 | | | 9.4 | 23.7 | 2.7 | 2.2 | ND | 25.9 | 3.7 | 3.8 | 11.0 | 23.4 |
| 1999 | | | 8.0 | 25.1 | 2.5 | 3.8 | 20.0 | 49.6 | 2.9 | 4.5 | 10.0 | 23.1 |
| 2000 | | | 8.9 | 25.9 | 2.5 | 2.9 | 23.0 | 53.5 | 3.2 | 4.7 | 9.6 | 19.4 |
| 2001 | | | 9.1 | 26.3 | 2.7 | 4.3 | 12.0 | 23.5 | 3.4 | 5.5 | 11.0 | 22.6 |
| 2002 | | | 9.4 | 26.2 | 2.7 | 4.4 | 11.8 | 23.5 | 3.7 | 6.1 | 11.0 | 21.8 |
| 2003 | | | 9.5 | 27.5 | 2.8 | 4.4 | 25.2 | 58.1 | 4.0 | 6.8 | 11.7 | 24.4 |
| **Average** | **41.2** | **109.9** | **7.12** | **19.07** | **2.56** | **2.17** | **14.00** | **29.44** | **2.69** | **3.26** | **11.19** | **24.84** |
| **Annual change** | | | **0.18** | **0.69** | **0.01** | **0.17** | **0.58** | **1.61** | **0.14** | **0.38** | **-0.21** | **0.87** |

## Table 4. Chloride Levels (mg/L) in Natural Springs

| **Sample Site** | Arboretum Spring | Monroe Street Spring | East Towne Spring |
|---|---|---|---|
| 2001 | 97 | 83.75 | 60.35 |
| 2002 | 98.55 | 85.75 | 54.55 |
| 2003 | 96.42 | 86.96 | 51.57 |
| **Average** | 97.32 | 85.49 | 55.49 |

## Table 5. Yearly Chloride Values (mg/L) - Madison Area Lakes

| | Mendota | | Monona | | Waubesa | | Kegonsa | | Wingra | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | Na | Cl | Na | Cl | Na | Cl | Na | Cl | Na | Cl |
| 1972 | NA | 13 | NA | 23 | NA | 26 | NA | 22 | NA | 58 |
| 1973 | NA | 14 | NA | 23 | NA | 24 | NA | 24 | NA | 63 |
| 1974 | NA | 15 | NA | 22 | NA | 22 | NA | 21 | NA | 51 |
| 1975 | 8.0 | 15.2 | 12.8 | 22.8 | 12.4 | 21.9 | 11.9 | 21.4 | 23.5 | 45.9 |
| 1976 | 7.5 | 15.7 | 12.7 | 22.3 | 12.9 | 22.7 | 12.1 | 22.8 | 25.2 | 51.3 |
| 1977 | 8.9 | 16.3 | 13.5 | 23.3 | 13.1 | 20.2 | 12.8 | 22.6 | 25.2 | 52.9 |
| 1978 | 8.8 | 16.3 | 13.3 | 24.0 | 12.4 | 21.8 | 11.4 | 22.9 | 19.5 | 39.6 |
| 1979 | 8.4 | 16.6 | 11.8 | 23.1 | 12.4 | 23.5 | 11.4 | 20.5 | 19.9 | 35 |
| 1980 | 9.0 | 18.4 | 13.6 | 25.3 | 12.3 | 25.3 | 12.7 | 24.7 | 23.9 | 50.7 |
| 1981 | 9.1 | 18.7 | 13.0 | 24.7 | 12.8 | 25.1 | 12.5 | 23.7 | 23.6 | 50.9 |
| 1982 | 10.1 | 20.3 | 13.7 | 25.5 | 13.4 | 25.8 | 12.4 | 24.8 | 24 | 50.4 |
| 1983 | 9.9 | 17.8 | 13.8 | 25.4 | 13.8 | 26.3 | 12.7 | 25.0 | 24.4 | 52.4 |
| 1984 | 10.0 | 19.7 | 14.8 | 26.6 | 14.7 | 27.7 | 13.1 | 25.3 | 25.8 | 53.8 |
| 1985 | 11.3 | 20.7 | 15.7 | 27.7 | 15 | 28.1 | 14.3 | 27.2 | 29.6 | 56.2 |
| 1986 | 10.8 | 22.3 | 15.1 | 28.9 | 14.8 | 29.5 | 14.3 | 28.6 | 27.5 | 59.7 |
| 1987 | 9.7 | 24.3 | 12.9 | 30.1 | 12.9 | 29.9 | 12.4 | 30.4 | 22.7 | 58.1 |
| 1988 | 11.1 | 25.7 | 15.6 | 34 | 14.6 | 32 | 13.1 | 30.5 | 29.8 | 70.1 |
| 1989 | 11.7 | 26.8 | 17.4 | 37.4 | 16.9 | 33.1 | 15.4 | 31.7 | 38.2 | 82.3 |
| 1990 | 12.7 | 29.5 | 18.8 | 40.1 | 17.9 | 38.9 | 16.5 | 37.1 | 31.2 | 70.1 |
| 1991 | 12.7 | 29.5 | 18.8 | 40.1 | 18.1 | 38.9 | 16.7 | 37.1 | 31.2 | 75.9 |
| 1992 | 12.1 | 30.5 | 19.2 | 40.1 | 18.8 | 38.5 | 17.3 | 37.4 | 31.1 | 63.2 |
| 1993 | 13.5 | 31.2 | 19.0 | 38.8 | 19.4 | 39.5 | 18.1 | 37.0 | 31.3 | 65.7 |
| 1994 | 12.9 | 32.4 | 16.9 | 39.3 | 17.1 | 39.3 | 16.2 | 37.9 | 31.4 | 75.2 |
| 1995 | 13.4 | 31.5 | 17.8 | 39 | 17.3 | 38.6 | 16.3 | 36.9 | 31.5 | 69.7 |
| 1996 | 14.1 | 33.4 | 18.8 | 42.7 | 18.8 | 41.4 | 17.5 | 38.8 | 33.9 | 76.5 |
| 1997 | 15.6 | 37.0 | 21.2 | 46.7 | 19.9 | 46.0 | 17.9 | 41.3 | 41.3 | 87.9 |
| 1998 | 15.9 | 33.4 | 22.7 | 43.3 | 23.1 | 43.9 | 21.8 | 43.1 | 39.6 | 77.0 |
| 1999 | 22.7 | 33.3 | 23.0 | 42.5 | 23.9 | 42.5 | 22.5 | 40.0 | 36.4 | 76.2 |
| 2000 | 15.0 | 34.0 | 20.0 | 41.0 | 20.0 | 40.0 | 19.0 | 39.0 | 31.0 | 66.0 |
| 2001 | 15.9 | 35.2 | 22.2 | 43.9 | 22.4 | 45.7 | 20.4 | 42.4 | 39.2 | 81.8 |
| 2002 | 16.0 | 36.0 | 22.0 | 46.0 | 22.0 | 46.0 | 21.0 | 44.0 | 37.0 | 77.0 |
| 2003 | 16.7 | 37.5 | 23.4 | 47.4 | 22.6 | 45.9 | 21.1 | 44.3 | 41.5 | 88.2 |

NA = Data not available

## Table 6. Summary of Continuous Monitoring from Spring Harbor and Starkweather Creek

| | Spring Harbor Stormsewer | | Starkweather Creek |
|---|---|---|---|
| | Maximum Concentration | Total Amount in Stormsewer | Maximum Concentration |
| | | January - April | |
| | mg/L Chloride | tons Chloride | mg/L Chloride |
| 2003 | 26,000 | 0.14 | |
| 2004 | 36,000 | 0.18 | 1500 |
| | | | |
| | Chloride in Lake Mendota at Spring Harbor February 1 & 2, 2003 | | |
| | Spring Harbor | Acute toxicity* | Chronic Toxicity* |
| | mg/L Chloride | | |
| Under Ice | 320 - 1700 | 757 | 395 |
| Near Bottom | 920 - 3300 | | |

* = WI Admin. Code NR 105 Water Quality Criteria

## Table 7. Varied Source Comparisons of Salt Concentrations

| Sources of Water | Salt Concentrations mg/L. |
|---|---|
| Distilled | 0 |
| Rain | 10 |
| Pyramid Lake (saline lake, Nevada) | 5,200 |
| Ocean | 35,000 |
| Brine Well | 125,000 |
| Dead Sea | 250,000 |

## Table 8. Chloride Concentration Increases (mg/L) Madison Area Lakes from Salt Reduction Base Year 1972 to 2003

| Area Lake | 1972-73 Cl (mg/L) | 2003 Cl (mg/L) | % Increase |
|---|---|---|---|
| Mendota | 14 | 37.5 | **168** |
| Monona | 23 | 47.4 | **106** |
| Waubesa | 24 | 45.9 | **91** |
| Kegonsa | 24 | 44.3 | **85** |
| **Average of Yahara Lakes** | **21** | **43.8** | **109** |
| Wingra | 63 | 88.2 | **40** |