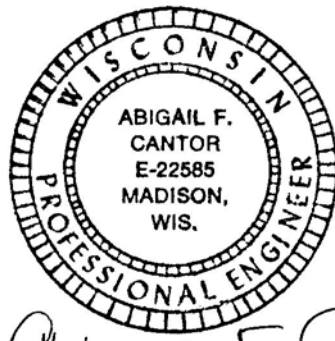


# Lead and Copper Rule Compliance Sampling

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## Madison Water Utility



*Abigail F. Cantor*

May 2010

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# Lead and Copper Rule Compliance Sampling

Madison Water Utility

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# Lead and Copper Rule Compliance Sampling

## Madison Water Utility

### History of Lead Control in Madison

In the Madison water system, lead was commonly used for water service lines from 1882, the inception of the Madison Water Utility, through 1927. Madison Water Utility has been replacing lead water service lines in the distribution system since the 1930s. This activity was intensified in 2000 under an agreement with the Wisconsin Department of Natural Resources (WDNR) to accelerate the prevention of lead transferred from lead pipes to drinking water. (See the agreement in Appendix A.)

The effort to replace lead water service lines is close to completion. The final step in the project is to show that lead concentrations in the distribution system are below the Action Level of 15 µg/L for “regulatory compliance” and are approaching 5 µg/L for complete “optimization” of controlling lead levels in the drinking water. The sampling protocol prescribed by the Federal Lead and Copper Rule (Code of Federal Regulations) must be used for this step.

This report summarizes the history of lead control in Madison, describes a successful approach to a similar problem in another water system, and recommends the next steps for Madison in planning and carrying out the Lead and Copper Rule sampling.

### Lead in Madison’s Distribution System

As stated, lead was commonly used for water service lines from 1882 through 1927. Eleven thousand lead water service lines were installed during this time period. From the 1930s to 1960s, the Utility began replacing lead services on a small scale, replacing them with copper when they leaked or when customers reported a low flow problem. During the 1970s, the Utility began replacing lead services when streets were reconstructed. In the late 1980s, Utility crews began replacing lead services during street resurfacing jobs. (PRS, 2006a)

Lead can also be found in other components of the distribution system. For example, Hersey water meters, some of which used lead weights, were used in the Madison water system from about the 1940s through the 1960s. The last of the lead-weight Hersey meters were replaced sometime in the 1990s. In about 2004, Madison Water Utility switched to non-lead “EnviroBrass” meters from Badger Meter, Inc. Older meters are still refurbished and reused, but when a meter is replaced after a lead service replacement, the new meter is always non-lead. (PRS, 2006a)

Brass Mueller corps and curb stops used in the Madison Water Utility distribution system contain about 5% lead (PRS, 2006a).

In addition, brass faucets and fittings that are purchased and installed by property owners in residential and commercial plumbing systems can contain lead.

## Initial Water Testing

The federal Lead and Copper Rule regulation was enacted in 1991. The regulation describes a protocol for sampling the water distribution system for lead and copper concentrations. If ten percent or more of the water samples have lead concentrations above the “Action Level” of 15 µg/L, then a water utility must alter the chemical composition of the water to make the water “less corrosive”. The lowest concentration in the top ten percent of the samples is called the “ninetieth percentile lead concentration”. (Code of Federal Regulations)

Just after the first Lead and Copper Rule sampling in Madison where the ninetieth percentile lead concentration was found to be 16 µg/L, a corrosion control investigation was initiated. That was in 1992. The true nature of Madison’s water would not be discovered until 2006. In the meantime, the water utility management made logical decisions based on investigation results regardless of popular anecdotal opinion concerning corrosion control.

The first tests on corrosion control in Madison were jar tests. In these tests, coupons of lead were suspended in jars of water. Using a statistical design to compare various treatments, the water in each jar used a different corrosion control chemical treatment. In this way, the transfer of lead into raw water was compared to water with sodium silicate addition, pH adjustment with sodium hydroxide, and a polyphosphate/orthophosphate blend addition. There was no change in lead levels with the sodium silicate addition; the increase of pH lowered the lead levels a little; the lead levels increased with the polyphosphate blend.

This information was used to set up an off-line pipe loop experiment using both old and new lead pipes. Three systems were set up in order to compare no treatment to two chemical treatments. Even though polyphosphate blend addition was shown to increase lead concentrations in the jar tests, the chemical was tested further in the pipe loop tests. This was because popular opinion at the time was to add a polyphosphate blend for corrosion control. Case studies were published in the technical literature, but many reports were contradictory. Chemical companies encouraged the use of polyphosphate blends, but the data they presented on the efficacy of the products were ambiguous. Plus, the chemical companies claimed that the jar tests did not represent an actual piping system. In addition, many smaller communities around Wisconsin were adding polyphosphate blends directly to the water system without previous off-line testing and with no distribution system monitoring. Based on the technical literature at the time, the Lead and Copper Rule and the federal and state regulatory agencies condoned and encouraged the use of polyphosphates for corrosion control. Finally, the use of orthophosphates was discouraged by chemical companies. It was rumored that pure orthophosphate would form a precipitate with calcium in the water that would obstruct pipelines. All of these factors led to the additional testing of polyphosphate blends in the Madison corrosion control investigation. A second treatment chosen was pH adjustment using sodium hydroxide. Here again, it was known that there were potential problems. Given the high hardness concentration of the Madison water, an increase in pH could easily set off the precipitation of calcium and magnesium into the pipe causing hydraulic problems. There were no other chemical corrosion control techniques available to test. The results of the tests showed that the pipeline and appurtenances plugged up with calcium and magnesium precipitate when the pH of the water was increased. The results

also showed that lead increased four times the concentration in untreated water when a polyphosphate blend was added. (Cantor, et. al., 2000)

## Subsequent Discussions

The results of the corrosion control investigation were presented to the WDNR. Madison Water Utility requested that the water system be allowed to skip the chemical alteration of the water as prescribed by The Lead and Copper Rule and move directly to a control step allowed in the Rule only if chemical treatment fails. That control step is the replacement of lead water service lines. The arguments for making this bold step were:

- Because of the water's potential for precipitating calcium, pH adjustment is not chemically viable.
- Because the water comes from twenty-three distinct sources with no common treatment or storage facilities, alkalinity adjustment is not economically viable.
- Sodium silicate did not show any benefit in jar tests. Plus, there is little information on the use of sodium silicates.
- Polyphosphates increased the lead concentration in the water. In addition, there was concern about adding phosphorus to water that will run off into the surrounding lakes where nutrients were already a problem. The wastewater treatment plant would also be responsible for removing the phosphorus for water that went through the wastewater system so that the Clean Water Act regulations would not be compromised.
- Orthophosphate usage was discouraged because of a possible precipitate even though the technical literature indicated that the chemical may be effective in lowering the lead levels. Nevertheless, the phosphorus discharge to the environment was a problem as described previously.
- There are no other chemical corrosion control techniques available.

Because of the emphasis that the Lead and Copper Rule has on chemical alteration of water for corrosion control, the WDNR requested that pipe loop tests be run using orthophosphate for corrosion control.

## Continued Testing

In 1998, the pipe loop tests with orthophosphate were run. Both old and new lead pipes were used. The orthophosphate successfully lowered the lead levels. (Cantor, et. al., 2000)

However, the Madison Metropolitan Sewage District had recently completed the installation of a biological phosphorus removal system that depended on a particular ratio of organic matter to phosphorus. If phosphorus was to be added to the drinking water, the removal system would not work properly and a chemical phosphorus removal system would need to be added.

In addition, the water that would runoff directly to the lakes would carry phosphorus with it. There was already discussion in the city council about banning phosphorus lawn fertilizers in Madison to prevent nutrient-laden runoff.

The WDNR then agreed that removing lead water service lines as a means of corrosion control was the only reasonable option available.

## Complete Lead Service Line Replacement

The WDNR also stated that, in accordance with the Lead and Copper Rule, a large system like Madison must achieve a 90<sup>th</sup> Percentile lead concentration of 5 µg/L in order for the water system to be deemed “optimized” for lead corrosion control. In order to achieve this low concentration, however, the WDNR required the utility to remove the complete lead service line. This presented a problem in that the water utility owns the water service line up to the curb stop at a private building and the property owner owns the service line from the curb stop to the building. Property owners would have to be encouraged to replace their portion of the service line and the cost of doing so would need to be addressed.

These were the considerations taken into account by Madison Water Utility and the Madison Common Council. They concluded that replacement of the customer side of lead service lines in the City was of benefit not only to each individual customer, but to the utility and community as a whole in meeting state and federal drinking water standards and avoiding the cost to all customers of adding corrosion control chemicals to the water system indefinitely. The lead service line replacements would also avoid the cost and environmental impact of adding phosphorus to wastewater streams.

The utility, for which rates are regulated by the Public Service Commission of Wisconsin (PSCW), requested that the PSCW include half the cost of replacing customer lead service lines in its rate base. The PSCW denied the request, rejecting the utility's arguments about the benefits to the utility and community and expressing the opinion that all water customers should not be burdened with any cost for replacing customer-owned service lines. This would set a precedent for other customer-owned systems, such as electrical wiring, which must be kept up to code at the customers' expense.

Subsequently, the Common Council approved a plan to place half the cost of replacing customer lead service lines on sewer rates, for which the PSCW did not have regulatory jurisdiction. The City justified this by showing a substantial avoided cost to sewer customers by implementing a complete lead service replacement program as opposed to adding corrosion control chemicals to drinking water, which would need to be removed at the wastewater treatment plant. Madison approved a complete lead service replacement program in February 2000, with a goal of replacing all lead water service lines in the City by 2011. Customers replacing lead service lines were to be reimbursed for half the cost of replacing those lines up to \$1000 reimbursement per property

On January 1, 2001, the initiation of the complete lead service line replacement program, there were approximately 6,000 existing Water Utility side services and 5,000 customer-side services. (PRS, 2006a)

## Follow-up Monitoring on Lead Service Line Replacement

In 2003, Madison Water Utility initiated a special project to assess the success of the lead line replacement program in terms of achieving optimal corrosion control. The study found that total lead concentration at a residence with a lead service line in Madison is typically seen to be erratic. Figure 1 shows that an individual site can have high lead at times and low lead at other times. After lead line replacement, the erratic behavior of total lead concentration continues for three or four years (Figure 2) and then appears to subside.

This was a surprising finding to see that lead can persist in a plumbing system several years after the source of lead has been removed.

This happens because lead is found in two forms in the water. The total lead concentration is actually a summation of lead dissolved in the water and lead entrained in the water as particulate matter. Figure 3 shows the dissolved fraction of lead in the 2003 water samples. By comparing Figures 2 and 3, it is seen that the erratic lead concentration is from lead particulate matter dislodging from pipe walls and arbitrarily becoming entrained in water samples. At the same time, dissolved lead concentration is lowered with lead service line replacement. The 2003 water sampling showed that the dissolved lead sampling results are at the desired goal of 5 µg/L (Figure 3). The data suggest that the lead-laden particulate matter is flushed out over several years after lead materials are removed from the plumbing system and a total lead concentration of 5 µg/L is eventually achieved (Figure 2). (Cantor, 2006)

The results of the lead line replacement monitoring study were discussed with WDNR. Essentially, Madison's compliance with The Lead and Copper Rule hangs on the random release of lead particulates into the water. This mechanism of the transfer of lead into water was not considered in The Lead and Copper Rule. In addition, until the Madison study was reported, the technical literature did not acknowledge this mechanism as a significant contributor to lead in drinking water.

## Pipe Film Analyses

In 2001, a lead water service pipe excavated in Madison was sent to Michael Schock, US Environmental Protection Agency Research Chemist, for examination. Around 2003, he reported that on top of a familiar lead carbonate compound (cerussite) on the pipe wall, there was a predominance of yet another lead compound, lead dioxide (plattnerite), which had not been expected or included in the existing theoretical model of lead corrosion. He explained that this relatively insoluble lead compound would signify water with very low aggressiveness. Mr. Schock published this and similar findings noting that lead concentrations found in Madison are more than a factor of 10 below the expected lead concentrations from the theoretical model (Lytle and Schock, 2005).

Three more lead pipes were sent to Michael Schock for analysis in May and September 2005. These three pipes also had cerussite overlaid by plattnerite on the pipe wall, but there was an additional factor. A scale layer of manganese and iron compounds was observed on the pipe wall.

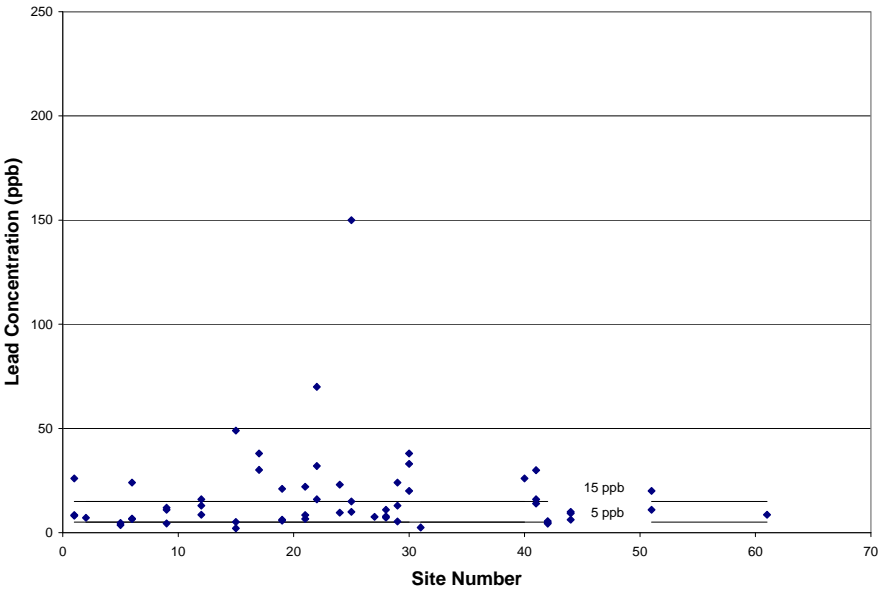
Mr. Schock reported (Schock, et. al., 2006): "Since lead compounds are intermingled with the manganese and iron scale layers, and it is probable that lead ions are sorbed to the oxyhydroxide surfaces, destabilization of these manganese/iron deposits could release microparticles intermittently."

The role of manganese scale in Madison was confirmed in further pipe film analysis by Dr. Barry Maynard and Dr. David Mast, professors at University of Cincinnati, in a 2006 AWWA Research Foundation study (Maynard & Mast, 2006).

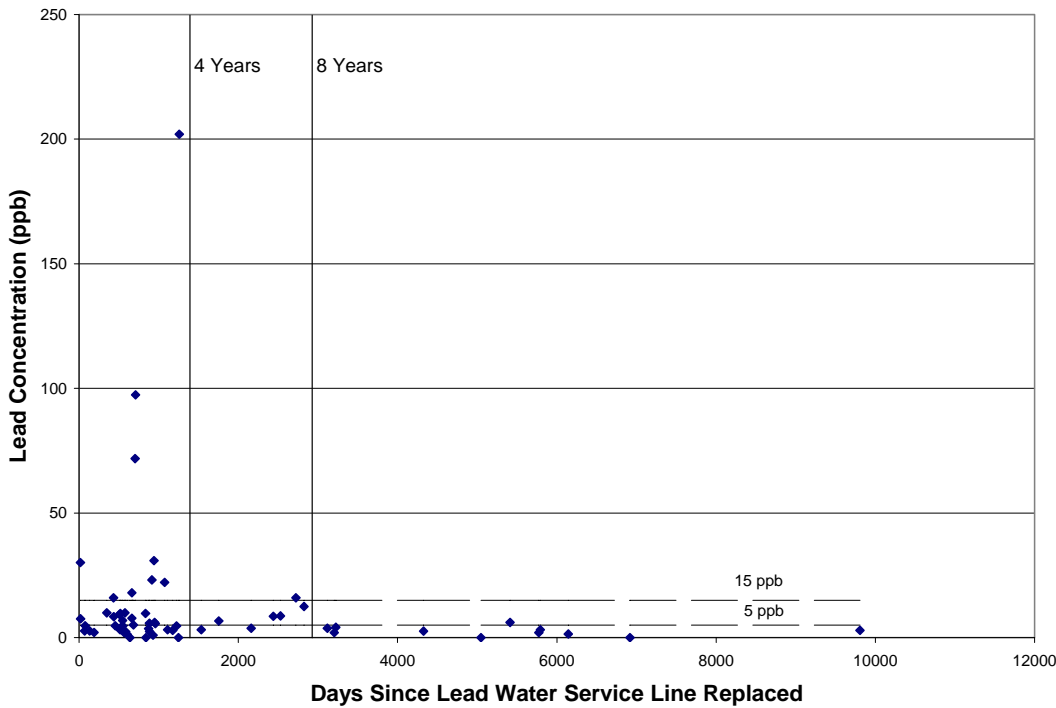
Indeed, the 2003 lead monitoring studies in Madison had shown lead in the drinking water to be mostly in particulate form. Only in 2006 was it understood that manganese scale played a major role in holding and randomly releasing lead measured as particulates into the drinking water.



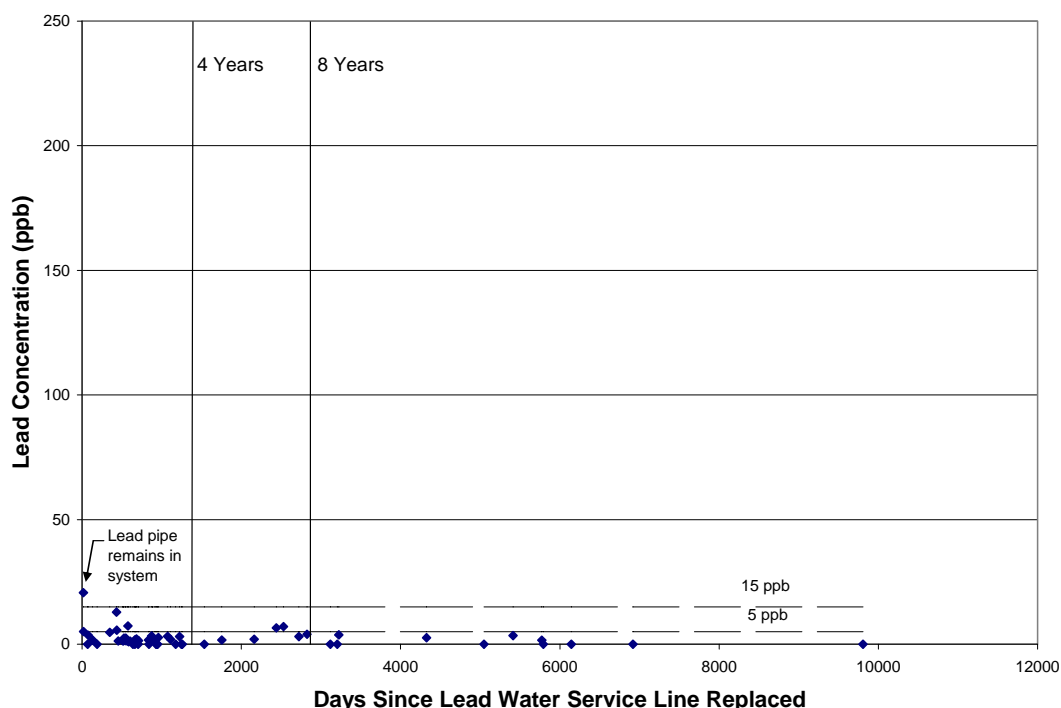
**Figure 1. Madison Water Utility: Total Lead Concentrations at Residences with Lead Water Service Lines (Cantor, 2006)**



**Figure 2. Madison Water Utility: Total Lead Concentrations at Residences After Lead Water Service Line Replacement (Cantor, 2006)**



**Figure 3. Madison Water Utility: Dissolved Lead Concentrations at Residences After Lead Water Service Line Replacement (Cantor, 2006)**



## Summary

In hindsight, the decision to replace lead service lines rather than alter the water chemistry still stands as a good one. As discussed previously, it is now known that Madison water already offers minimum aggressiveness toward lead. It is the presence of manganese scale on the pipe wall that captures, stores, and randomly releases lead particulates into the drinking water.

## Publications about the Madison Experience

The investigations in Madison have served as an example to the national drinking water community. Discoveries in Madison contradicted assumptions about lead release into drinking water that have been stated in The Lead and Copper Rule and in technical literature. Therefore, the investigators, Abigail Cantor of Process Research Solutions, LLC, Michael Schock of US Environmental Protection Agency, and Barry Maynard and David Mast of University of Cincinnati, have felt it important to publish the findings from Madison data. The important discoveries have been:

- Polyphosphate corrosion control products are not necessarily successful at controlling lead or copper concentrations in drinking water. Ironically, the chemical can, in some cases, increase the lead or copper concentrations instead of decreasing them. Madison Water Utility tested a polyphosphate product to lower lead concentrations in the drinking water; the off-line tests showed that the lead concentration increased four times over that in untreated water.

- In some cases, a very protective pipe film can form naturally in the water practically stopping uniform corrosion in a water system. Madison's water was found to form this highly protective film.
- Manganese scale which precipitates and builds up in water distribution systems when found in source water has a tendency to capture dissolved and particulate lead (and other metals) from the water that flows past. In this way, lead is stored in the distribution system until it is released randomly to the consumers' taps where it is measured as lead particulates.
- Not all increases in lead and copper in drinking water are caused by uniform corrosion as the primary drinking water regulation, The Lead and Copper Rule, assumes. Madison has been shown to have minimal uniform corrosion.

The following international publications use Madison as an example to alert other water utilities to contradictions and discoveries for lead control in drinking water:

Cantor, A.F., D. Denig-Chakroff, R.R. Vela, M.G. Oleinik, D.L. Lynch (2000). "Use of Polyphosphate in Corrosion Control," *Journal of the American Water Works Association* (92:2:95).

Cantor, A.F. (2006). "Diagnosing Corrosion Problems Through Differentiation of Metal Fractions," *Journal of the American Water Works Association* (98:1:117).

Cantor, A.F. & S. Estes-Smargiasi (2006). "Report on Lead Service Line Replacement AwwaRF Study", Proceedings of the American Water Works Association 2006 Water Quality and Technology Conference Nov. 5-9, 2006 (Denver, CO).

Lytle, D.A. and M.R. Schock (2005). "Formation of Pb(IV) Oxides in Chlorinated Water," *Journal of the American Water Works Association* (97:11:102).

Maynard, B. & D. Mast (2006). Composition of Interior Scales on Lead Source Materials. Proceedings of the American Water Works Association 2006 Water Quality and Technology Conference Nov. 5-9, 2006 (Denver, CO).

Sandvig, A., P.Kwan, G. Kirmeyer, B. Maynard, D. Mast, R.R. Trussell, S. Trussell, A. Cantor, & A. Prescott (2008). *Contribution of Service Line and Plumbing Fixtures to Lead and Copper Rule Compliance Issues*. AWWA Research Foundation (Denver).

Cantor, A.F (2009). *Water Distribution System Monitoring: A Practical Approach for Evaluating Drinking Water Quality*. CRC Press (Boca Raton).

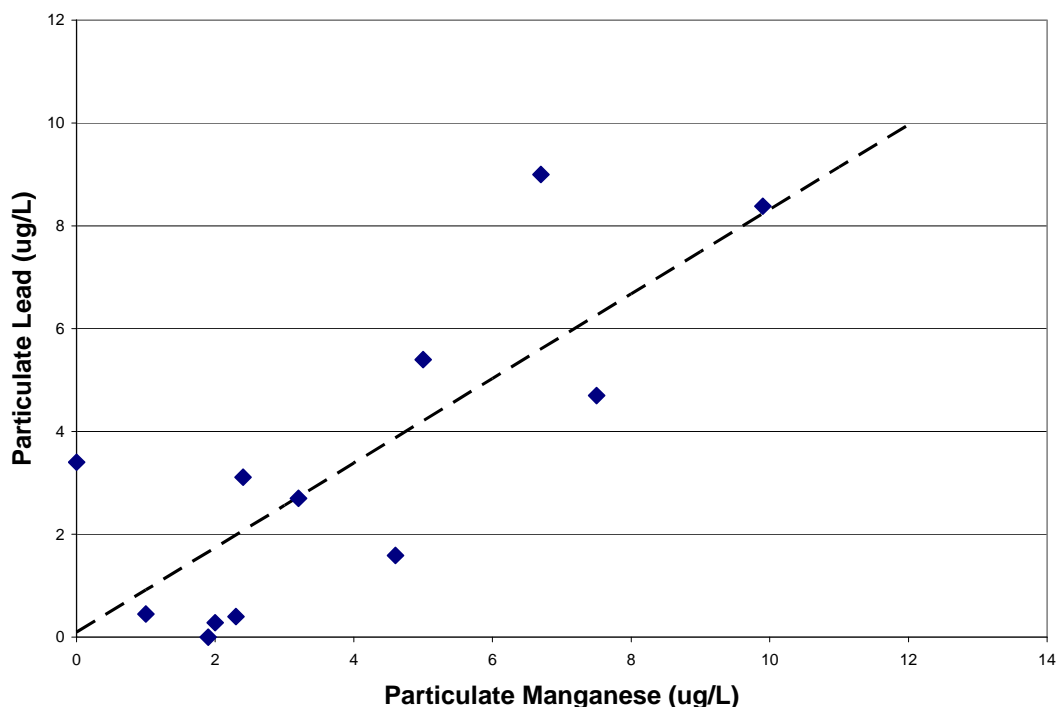
## Lead and Copper Rule Sampling Results from Other Utilities After Unidirectional Flushing

The discoveries from Madison Water Utility investigations have been carried forward to subsequent water quality investigations by Process Research Solutions. Many groundwater systems in Wisconsin and around the country have iron and manganese dissolved in well water from the aquifer. These metals oxidize in the distribution system and precipitate as a solid on the distribution system pipe walls. Both iron and manganese have a tendency to form chemical bonds with other metals passing by the surface of the scales. Manganese, especially, has a tendency to "sorb" lead in this way. When pieces of

the manganese scale inevitably break off, the lead “piggybacks” with the manganese and can end up at the consumers’ tap.

Marshfield Utilities in western Wisconsin showed the same pattern of particulate lead randomly occurring at consumers’ taps as was seen in Madison. Marshfield has a presence of iron and manganese varying from well to well just as Madison does. A moderate relationship was found between particulate manganese and particulate lead at consumers’ taps as shown in Figure 4 (PRS, 2006b).

**Figure 4. Marshfield Utilities: Manganese versus Lead Particulates in Drinking Water**



It was recommended that Marshfield perform uni-directional flushing of water mains to efficiently clean out manganese scales (PRS, 2006b). The utility performed this flushing in the summer of 2007 as well as flushed critical water service lines and has completed follow-up Lead and Copper Rule sampling. The utility is now in compliance with The Lead and Copper Rule and maximum lead levels have dropped from 220 µg/L to 10 µg/L, ninetieth percentile lead levels have dropped from 32 µg/L to 8 µg/L (PRS, 2008). Table 1 and Figure 5 illustrate the improvements made in controlling lead by cleaning out the manganese scales in Marshfield.

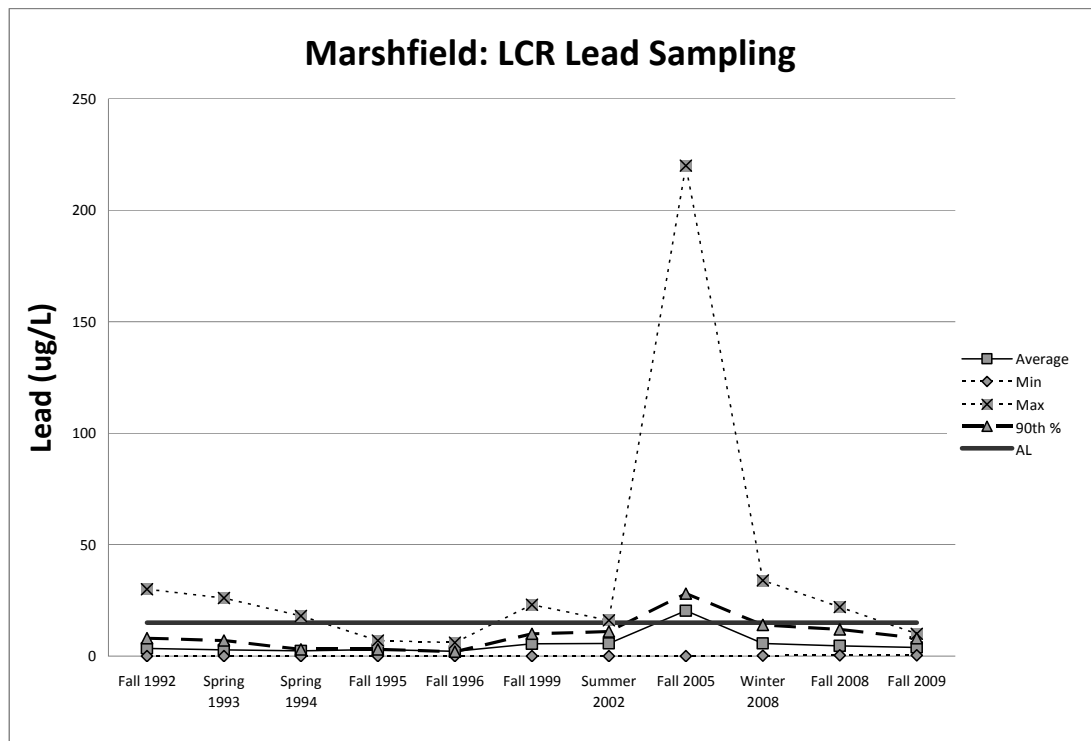
Madison Water Utility has also been efficiently cleaning water mains with uni-directional flushing since 2006. The motivation to do so was from customer complaints about excessive manganese particulates in the water. The first pipe film analysis report that found manganese to be a significant mechanism to holding and releasing lead into the water (described above) was received a few weeks before the flushing program began. It was realized at that point that the flushing program not only benefits the issue with water discolored by manganese but also addresses the lead particulate issue as well. Now that data from Marshfield Utilities’ experience shows success of uni-directional flushing with

lowering lead levels, it is expected that Madison's Lead and Copper Rule sampling will show the system in compliance.

**Table 1. Marshfield Utilities: Lead and Copper Rule Sampling Statistics**

Year	Average Value	Standard Deviation	Max Value	90th Percentile
1992	2.5	6.3	30	8
1993	1.8	4.1	26	7
1994	1.4	3.3	18	4
1995	2.1	1.6	7	4
1996	1.3	1.6	6	3
1999	4.7	4.9	23	12
2002	4.9	4.3	16	13
2005	20	48.7	220	32
2008, winter	5.7	6.3	34	14
2008, fall	4.6	4.9	22	12
2009, fall	3.9	2.5	10	8

**Figure 5. Marshfield Utilities: Lead and Copper Rule Sampling Statistics**



Marshfield's experience also suggests that perhaps the lead water service lines did not need to be replaced in Madison; uni-directional flushing alone may have solved the problem. That may be so. However, that could not have been known in 1991 or even 2003. It was the Madison experience that paved the way into understanding the lead issue for the drinking water industry. In addition, lead water service lines should be replaced anyway because lead can be transferred to water by a number of mechanisms (Cantor, 2009). As long as major sources of lead exist in a system, it poses a threat to water quality. It is also known now that replacing both the utility's side and the property

owner's side of the lead water service line is imperative as the human exposure to lead is greatly increased if only part of the line is replaced (Sandvig, et. al., 2008). Other water utilities should follow Madison both in removing lead from the distribution system over time and in efficiently cleaning water mains and water service lines routinely.

## Sampling Plans

### Lead and Copper Rule Sampling

#### Monitoring Period

At the completion of the lead service line replacement program in 2010, Madison Water Utility must perform Lead and Copper Rule sampling at one hundred residences and prove compliance in two successive six month periods (January to June 2011 and July to December 2011).

If the Action Levels for lead and copper (15 and 1300 ug/L, respectively) are not exceeded for the two monitoring periods, sampling is expected at fifty sites annually for two more years (2012 and 2013). If compliance is again proven during those sampling events, sampling frequency moves to every three years where the cycle would begin in July 2014.

If, during the two six month sampling periods in 2011, the lead ninetieth percentile concentration is 5 µg/L, then the water system is exempt from the annual sampling requirements in 2012 and 2013 and the sampling frequency moves to every three years, where the cycle would begin in July 2014 for fifty sites. Table 2 summarizes the monitoring requirements.

**Table 2. Madison Water Utility: Lead and Copper Rule Sampling Schedule**

Item	Year	Months	Number of Sites	Comments
A	2011	January to June	100	If 90 <sup>th</sup> percentile lead is 15 ug/L, then in compliance; continue to Item C. If 90 <sup>th</sup> percentile lead is 5 ug/L, then optimized; jump to Item E.
B	2011	July to December	100	
C	2012	July to December	50	
D	2013	July to December	50	
E	2014	July to December	50	

## Sampling Sites

The Lead and Copper Rule designates criteria for selecting residences as sampling sites. The goal is to sample sites with criteria categorized as "Tier 1". If sites are not available, "Tier 2" criteria are used.

The original Lead and Copper Rule sampling sites that had lead water service lines are no longer considered "Tier 1" sites because the lines have been replaced. In fact, there are no longer any lead water service line sites in Madison. Therefore, Tier 1 sites are now defined as those that contain copper pipes with lead solder installed after 1982. Since lead solder was banned around 1984, residences built in 1983 and 1984 are eligible as Tier 1 Lead and Copper Rule sampling sites. Thirty-seven of the original one hundred sampling sites are still considered as Tier 1 sites under these criteria. By regulation, those sites must be included in the 2011 Lead and Copper Rule sampling, if possible. See Appendix B for a list of the original sampling sites.

About five hundred other sites have also been identified as meeting the Tier 1 criteria. Outside of the original thirty-seven sites, the remaining sites from the list that cover as large a geographical area of the water distribution system as possible will be selected. See Appendix C for a list of possible sites.

Note that the consent order addendum states the compliance samples should be collected according to NR 809.547 and "within the area where lead water service lines were replaced". It is implied, but not stated, that compliance samples must meet the Tier 1 criteria. In Madison's case, there are no longer Tier 1 sites in that geographical area. However, there are Tier 1 sites available from the original sites sampled in 1991, which will be used, as stated previously. An additional sampling of sites that had lead service lines replaced will be performed in a separate investigation, but according to EPA guidance, sites where lead service lines are replaced no longer meet the criteria of a Tier 1 site, and may be removed from the sampling pool. This understanding of site selection is shared by the Wisconsin Department of Natural Resources.

## Protocol

The protocol for Lead and Copper Rule sampling should be as follows:

1. Select 100 potential sampling sites and some extra sites for back-up.
2. Contact the property owners by mail to determine if their residence fits the regulatory sampling requirements. Re-word the questions below for ease of answering and give property owners a means to respond easily.
  - a. Was the site built in 1983 or 1984?
  - b. Does the site have a copper plumbing system?
  - c. Is cold water treated on-site upon entering the building and before flowing to the building's faucets? If so, the residence is not eligible for sampling as the goal of sampling is to test the distribution system water and not water altered on-site. (Softening and filtration are forms of on-site treatment. Treatment of water to the hot water plumbing lines is acceptable.)

- d. Does the kitchen sink faucet have on-site treatment of cold water installed? If so, can it be removed temporarily for obtaining a water sample? If not, is there a bathroom sink faucet available without on-site treatment of cold water? (There must be a cold water faucet available in the residence where distribution system water is not altered by on-site treatment.)
  - e. Are there leaks in the plumbing system that prevents water to cease flowing into the plumbing system? If so, the residence is not eligible for sampling as water must not flow in the plumbing system during the required stagnation period before sampling. (New water meters have a small dial that will continue to turn when all faucets are closed if there is a leak. Confirm that the small dial does not turn when all faucets are closed and there is no water use in the building.)
3. With the responses, follow-up on sites that fit the sampling criteria with a description of sampling protocol and sampling schedule and ask the following questions:
  - a. Can the building occupants follow the required sampling protocol to obtain a water sample? (List the steps for obtaining a sample so that the commitment to sample is fully understood. The steps are described below.)
  - b. Are the building occupants willing to obtain water samples using the sampling protocol for the multiple sampling times required by the Federal drinking water regulation? See Table 2 for the sampling schedule.
4. Make arrangements with a drinking water certified laboratory to provide one liter bottles for metals analysis. The bottles should contain NO acid. Also make arrangements to ship or deliver water samples to them as soon after sampling as possible so that a portion of the sample can be filtered right away. Each one liter sample should be analyzed for Total Lead, Total Copper, and Dissolved Lead. If the budget allows, include Total Iron and Total Manganese analyses as well. The filtration and Dissolved Lead analysis are outside of the Lead and Copper Rule requirements. These steps are added to show the tendency of lead in Madison's water to be in particulate form. The Total Iron and Manganese analyses are also out of the scope of the Lead and Copper Rule, but are significant information for Madison. Sorption of lead by manganese (from source water scaling) and iron (from source water and from corroded galvanized iron pipe) appear to be the main mechanisms of lead transfer into water in Madison.
5. Distribute labeled sample bottles and instructions to all willing property owners at appropriate sites. Sample bottles and literature can be left on doorsteps. Bottle labels should include space for the property owner to write:
  - a. address
  - b. date and time that water stagnation began
  - c. date and time of sampling
  - d. designate if kitchen faucet or bathroom faucet was used



- e. designate if faucet had an aerator

Utility personnel should also record time of lab delivery. The laboratory, if possible, should record and indicate time of filtration.

6. Property owners must follow the sampling protocols as described below:
  - a. Determine the faucet where the water sample will be obtained. Use the kitchen sink faucet if there is no on-site treatment of cold water or if on-site treatment equipment can be removed temporarily. Use a bathroom sink faucet with no on-site treatment of cold water if the kitchen faucet does not meet the sampling requirements. If the selected faucet is a “mixing faucet” that mixes hot and cold water, make sure that it can be positioned to obtain cold water only.
  - b. If there is an aerator on the faucet, do NOT remove it. The US Environmental Protection Agency suggests that aerators should not be removed.
  - c. The sampling protocol requires that a six hour minimum stagnation period occurs before taking a water sample. Just before starting the stagnation period, run water at the designated sample tap until water from the water main (and not water from the building’s plumbing system) is flowing from the faucet. The length of time to run the water will vary with every building. A simple way to gauge this is to run water from the faucet until the water feels colder and possibly smells like chlorine. This is to make sure that the water tested begins with fresh water from the water main. This should not be an attempt to flush the water lines, but to simply fill the plumbing system with fresh water from the water main.
  - d. Do not use water in the building, including the flushing of toilets, for at least six hours. Also, make sure that there will be no automatic use of water during this time period, such as the automatic regeneration of water softeners or automatic filling of ice trays. It is very important that the water now stagnates in the building’s plumbing system for this time period. Place signs on sinks and toilets to remind building occupants that water is not to be used.
  - e. After at least six hours of stagnation, fill the one liter sample bottle to the brim with “first-draw” water from the faucet that has been selected as the sampling faucet. Remember: If the selected faucet is a “mixing faucet” that mixes hot and cold water, make sure to position it to obtain cold water only.
  - f. Cap the bottle tightly and fill out the label.
  - g. Contact Madison Water Utility immediately to pick up the sample. (Telephone: \_\_\_\_; Email: \_\_\_\_)
  - h. Set the sample bottle outside the front door for pickup.
  - i. Water can once again be used in the building. Re-install any treatment equipment that was temporarily removed and remove signs from sinks and toilets.

7. At the utility, check throughout the day for messages about samples available for pickup and pick them up as soon as possible.
8. After all samples for the day have been collected, pack them on ice in a cooler, fill out laboratory paperwork and ship or deliver them to the laboratory as soon as possible. Remind the laboratory that they are to filter a portion of each one liter sample as soon as possible for analysis of Dissolved Lead.
9. In cold weather, be careful that the samples do not freeze. Pick samples up quickly from residences or do not have property owners sample when the air temperature is too cold. If air temperature will be below 20 degrees F, do not ship the samples to a laboratory. Instead, keep samples in a refrigerator until air temperature is forecast to stay warmer during the shipping period. If samples must be kept in a refrigerator, perform a field filtration (Cantor, 2009) of a portion of each one liter sample into appropriate metals bottles from the laboratory. Label with address of sampling site, mark label as filtered sample, keep in refrigerator, and ship to laboratory with the other samples for analysis of Dissolved Lead.
10. As soon as laboratory results are reported to the utility, send a letter to the property owner reporting and explaining the results.

## Lead and Copper Rule and Sampling Issues

Details in this report were discussed at a meeting between representatives of WDNR, Madison Water Utility, and Process Research Solutions on March 23, 2010. The following details of the Lead and Copper Rule and sampling protocols were acknowledged and agreed upon.

### Alternative Corrosion Control Approach

Madison Water Utility has been allowed to adopt a corrosion control strategy that diverges from the chemical approach described in the Lead and Copper Rule. Madison's technique is:

- the elimination of lead water service lines in order to eliminate a significant source of lead in the water system
- uni-directional flushing of water mains and some water service lines in order to remove manganese and iron scales that hold and randomly release lead particulates.

The approach appears to be effective based on results from a 2003 study of residences after lead service lines were replaced. The approach is also given credence with the success of Marshfield Utilities in coming into compliance with the Lead and Copper Rule by means of uni-directional flushing without lead water service line replacement.

### Use of Data from Old Sites

A subset of the original one hundred residences used in the 1992 Lead and Copper Rule sampling that had lead service lines is no longer considered by the Lead and Copper Rule to be appropriate sampling sites for further regulatory sampling. This is because they no longer fit descriptions of "Tier 1" or "Tier 2" sites. That is, they no longer have lead water

service lines, nor are they residences built in 1983 or 1984 with lead solder in the plumbing.

Nevertheless, these sites will be sampled for lead and copper in a special investigation to gauge the effectiveness of the lead water service line replacement program and provide feedback to property owners who originally participated in Lead and Copper Rule sampling. The data from that investigation are not eligible to be used in the pool of data for Lead and Copper Rule compliance.

#### “Compliance” versus “Optimization”

The Lead and Copper Rule distinguishes between water systems that are in “compliance” with the Rule and those that are “optimized” against uniform corrosion. A water system is in compliance if the ninetieth percentile sample result from a sampling event shows lead in a concentration less than or equal to 15 µg/L and copper in a concentration less than or equal to 1300 µg/L. The Rule is specific as to what a water system must do if out of compliance.

A water system is “optimized” if the ninetieth percentile sample results from a sampling event shows lead in a concentration of 5 µg/L or less. The regulator for a large water system can determine if the system can do more to not only be in compliance but also to reach the 5 µg/L ninetieth percentile concentration. In that case, the regulator can require more corrosion controls be applied. In the case of Madison, WDNR, the regulator, acknowledges that the water system has been greatly studied and water quality characteristics defined. If Madison meets compliance criteria, WDNR will consider the water system optimized as well.

#### Exemption from Extra Sampling

The Lead and Copper Rule also states that if a water system is “optimized”, as defined by achieving a ninetieth percentile lead concentration of 5 µg/L or less in two successive sampling periods six months apart, the water system will be exempt from two more successive annual sampling periods. Instead, the water system will go directly to the three year sampling cycle. This exemption will apply to Madison if such low lead levels are achieved during the two 2011 sampling periods.

#### Use of Fresh Water for Sampling

Established through many water system investigations, including the ones in Madison, Process Research Solutions’ protocols for proper lead and copper sampling includes drawing in fresh water from a water main to a sample tap before starting the stagnation period. This is done because the goal of Lead and Copper Rule sampling is to test the water provided by the water utility and not the water that has been altered already by on-site plumbing. This technique also makes the comparison of results from site to site more scientific in that all sites begin with the same fresh water. This eliminates comparing sites where water may have sat stagnate for weeks or months while the homeowners were on vacation to sites where a large family is constantly using water. That is, all sites become equal to test the water utility’s water when fresh water is drawn to the sample tap before the stagnation period.

Note, however, that there has been much national discussion about the protocols of Lead and Copper Rule sampling. Much of this comes from a continued debate concerning spikes of lead concentrations in residences in Washington, D.C. Part of the debate

includes an outcry against flushing of plumbing systems before starting the stagnation period before sampling. Critics say that this flushes out the lead debris that needs to be captured in a water sample for accurate accounting of lead in the water system.

The technique of drawing in fresh water to test water from water mains should not be confused with flushing the water lines in order to “destroy the evidence.” Protocols in Madison acknowledge that particulate lead and lead debris in pipelines are important to capture as the history of lead in Madison’s water system illustrates.

#### Use of Aerators during Sampling

That being said, the US Environmental Protection Agency (EPA) protocol to keep aerators on during sampling is counter to the protocols used by Process Research Solutions for water quality investigations. Critics claim that the lead particulates and lead debris that have accumulated in an aerator are discarded when the aerator is removed and, therefore, the lead concentrations in a water system are not represented properly. However, it is the observation at Process Research Solutions that an aerator blocks the lead particulates from entering the water sample and, in that way, the lead concentrations in a water system are not represented properly with an aerator installed.

In addition, the use of an aerator with accumulated lead debris represents an accumulation that happened over time in the past. If one considers that the goal of the Lead and Copper Rule sampling is to determine the reactions and interactions that occur during a stagnation period between fresh utility water and premise plumbing, then the results of interactions and reactions from outside that time period should be eliminated.

Because US EPA has written a memo that aerators are to remain on and because some people may not be able to remove the aerators, the protocol in Madison will be to keep the aerators on. Samples will be identified as having been taken with an aerator on the sample tap and also will be identified if an aerator does not exist. Data will be analyzed outside of the Lead and Copper Rule protocols to see if there are differences in the results for this sample set.

#### Analysis of Dissolved Lead

The Lead and Copper Rule calls for the analysis of Total Lead and Total Copper in water samples. Because it is acknowledged that higher lead concentrations in Madison’s water are typically in particulate form, analyses will also be performed for Dissolved Lead. The difference between Total Lead and Dissolved Lead is Particulate Lead. The data will, then, show what percentage of high lead concentrations is actually in particulate form.

#### Response to High Particulate Lead

It has been acknowledged that Madison’s form of corrosion control is to efficiently clean pipes of manganese and iron scales that can capture lead from and randomly release lead into the water. To this end, if any Lead and Copper Rule sampling site shows that lead is elevated AND that the lead is in particulate form, the water service line and premise plumbing will be efficiently flushed to clean out the debris in order to solve the problem of high lead. The site will be re-sampled – either during the same sampling period or during the next sampling period. If the site is re-sampled during the same sampling period, the data will be included in the total sampling dataset. The original data point from that site will also remain in the dataset. The complete dataset will be used to determine the ninetieth

percentile lead concentration. This protocol was used in Marshfield and was agreed to by WDNR ahead of the sampling event.

This protocol is done because cleaning water pipes IS the corrosion control technique in the water system and will be used as a routine maintenance protocol outside of Lead and Copper Rule sampling.

#### Revisions to This Report

This report will be reviewed by WDNR. Any corrections by WDNR or others will be made in a revised report and chronicled in Appendix D.

### Additional Sampling

#### Goals

As previously stated, beyond the required Lead and Copper Rule sampling, it is desired to re-sample the subset of the one hundred sites of the original Lead and Copper Rule sampling from 1992 that had a lead service line. All of these sites have had the complete lead water service line replaced. These data are not eligible to be used for Lead and Copper Rule sampling results, but they will serve to gauge the effectiveness of the lead water service line replacement program and provide feedback to property owners who originally participated in Lead and Copper Rule sampling.

#### Monitoring Period

This sampling can be performed at any time as it is investigative and not a regulatory action. It is suggested that the sampling be done during June to September 2010 before the regulatory sampling.

#### Sampling Sites

Use the subset of the one hundred sites of the original Lead and Copper Rule sampling from 1992 that had a lead service line. If any property owner can no longer participate in this sampling, it is not necessary to find a different site. See Appendix B for a list of the original 100 sampling sites and the subset that had lead water service lines.

#### Protocol

Perform this investigative sampling starting with Step #4 of the protocol described previously for Lead and Copper Rule sampling. The goal is to compare these results to the 1992 Lead and Copper Rule results and to the new 2011 Lead and Copper Rule results.

## References

Cantor, A.F., D. Denig-Chakroff, R.R. Vela, M.G. Oleinik, D.L. Lynch (2000). "Use of Polyphosphate in Corrosion Control," *Journal of the American Water Works Association* (92:2:95).

Cantor, A.F. (2006). "Diagnosing Corrosion Problems Through Differentiation of Metal Fractions," *Journal of the American Water Works Association* (98:1:117).

Cantor, A.F. (2009). *Water Distribution System Monitoring: A Practical Approach for Evaluating Drinking Water Quality*. CRC Press (Boca Raton).

Lytle, D.A. and M.R. Schock (2005). "Formation of Pb(IV) Oxides in Chlorinated Water," *Journal of the American Water Works Association* (97:11:102).

Code of Federal Regulations, Ch. 40, Part 141, Subpart I (aka The Lead and Copper Rule)

Process Research Solutions, LLC (2006a). AWWARF Project 3018: Madison (Wisconsin) Water Utility Lead Service Line Replacement Study (engineering report with Information included from Madison Water Utility personnel:

- Doug De Master, Engineering Systems and Mapping Engineer
- Dan Rodefled, Field Supervisor
- Robin Piper, Accountant
- Tony Mazzara, Water Meter Mechanic Leadworker
- Ken Key, Customer Service Manager

Process Research Solutions, LLC (2006b). "Corrosion Investigation: Marshfield Utilities" (engineering report).

Process Research Solutions, LLC (2008). "Corrosion Investigation Follow-up: Marshfield Utilities" (engineering report).

Sandvig, A., P.Kwan, G. Kirmeyer, B. Maynard, D. Mast, R.R. Trussell, S. Trussell, A. Cantor, & A. Prescott (2008). *Contribution of Service Line and Plumbing Fixtures to Lead and Copper Rule Compliance Issues*. AWWA Research Foundation (Denver).

Schock, M.R., et. al. (2006). "Scale Analysis for Madison, Wisconsin Samples" (private report).

## Appendix A: WDNR Consent Order and Revision



State of Wisconsin \ DEPARTMENT OF NATURAL RESOURCES

Tommy G. Thompson, Governor  
George E. Meyer, Secretary

101 S. Webster St.  
Box 7921  
Madison, Wisconsin 53707-7921  
Telephone 608-266-2621  
FAX 608-267-3579  
TDD 608-267-6897

COPY

December 21, 2000

Mr. David Denig-Chakroff, General Manager  
Madison Water Utility  
523 East Main St.  
Madison, WI 53703

Casetrack # 2000-COEE-001

SUBJECT: ~~Consent Order~~ #2000-COEE-001

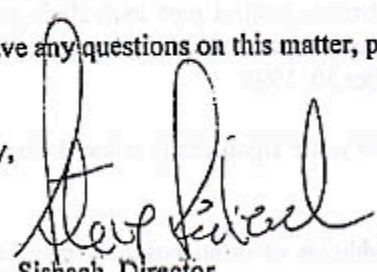
Dear Mr. Denig-Chakroff:

Enclosed is your copy of the signed Consent Order. Please copy and forward to Mayor Susan Baumann, Ray Fisher, City Clerk, Dean Brasser, City Comptroller, and City Attorney, Eunice Gibson.

Failure to abide by the conditions of this Consent Order may cause the Department to pursue further enforcement action.

If you have any questions on this matter, please contact Mark Nelson, Water Supply Specialist, at 267-4230.

Sincerely,

  
Steven L. Sisbach, Director  
Office of Environmental Enforcement  
Bureau of Law Enforcement

c: Mark Nelson - DG/2  
Edwina Kavanaugh - LS/5  
Tim Coughlin - SCR

Quality Natural Resources Management  
Through Excellent Customer Service





**BEFORE THE  
STATE OF WISCONSIN  
DEPARTMENT OF NATURAL RESOURCES**

In the Matter of the Optimal Corrosion  
Treatment of the Public Water Supply of the  
City of Madison in Dane County, Wisconsin

)  
)  
)

FID No.:

Case No.: 2000-COEE-001

**FINDINGS OF FACT, CONCLUSIONS OF LAW AND CONSENT ORDER**

**FINDINGS OF FACT**

1. The City of Madison, ("City"), operates a community water system as defined in s. NR 809.04(4), Wis. Adm. Code, which supplies water for human consumption to residents of the City of Madison located in Dane County, Wisconsin.
2. As a community water system having at least 15 service connections or regularly serving an average of at least 25 individuals daily for at least 60 days in the year, the City of Madison system constitutes a "public water system" providing piped water for human consumption as defined in s. NR 809.04(48), Wis. Adm. Code.
3. In the interest of protecting public health and safety, the federal Safe Drinking Water Act ("SDWA"), 42 U.S.C. 300f-300j-26, and ch. NR 809, Wis. Adm. Code, require public water systems such as the City of Madison Water Utility to submit drinking water compliance samples for various chemical parameters, including lead and copper ("the Lead and Copper Rule"), as required in the annual monitoring schedule.
4. The City of Madison and its consultants completed a corrosion control pipe loop study as per a Consent Order executed on September 5, 1997, and submitted a report to the Wisconsin Department of Natural Resources ("DNR" or "Department") on September 30, 1998.
5. The report concluded that addition of orthophosphate to the water significantly reduced the amount of lead leached into the water in the pipe loop study.
6. The report also documented potential adverse impacts addition of orthophosphate may have on wastewater treatment processes and storm sewer discharges. The report recommended that the Madison Water Utility implement alternative means of complying with the Lead and Copper Rule.
7. In a letter dated December 10, 1998, the Department agreed to consider a proposal from the City to optimize corrosion control through a lead water service line replacement program if the proposal met specific conditions outlined in the letter.
8. The City submitted a Draft Lead Water Service Line Replacement Proposal and a time line for implementation to the Department on June 30, 1999.
9. The Madison Common Council adopted a lead water service line replacement ordinance, sec. 13.18, Madison General Ordinances, on February 1, 2000, which met the conditions required by the Department.



### CONCLUSIONS OF LAW

1. The Department has the authority under s. 281.17(8), Stats., to establish and administer a Safe Drinking Water Program, including issuance of rules. Such rules are contained in Chapter NR 809, Wis. Adm. Code.
2. This Order is reasonable and necessary to accomplish the purposes set forth in ch. 281, Stats., and is enforceable under ss. 299.95 and 299.97, Stats.

### CONSENT ORDER

The Wisconsin Department of Natural Resources orders and the City of Madison agrees to meet the following schedule of actions:

1. The City shall implement a lead water service line replacement program in accordance with Section 13.18, Madison General Ordinances. The City shall continue the replacement of the City-side lead water service lines according to a schedule that will complete such replacement by January 1, 2011. The Department may require the City to submit for Department approval a schedule setting dates by which the City shall meet interim lead water service line replacement goals (e.g., 40% of all lines replaced by January 1, 2005). The Department agrees that it shall not require such schedule so long as the City is undertaking reasonable efforts to comply with the January 1, 2011 completion date. The City agrees to submit such schedule upon reasonable request by the Department and to comply with the schedule as approved by the Department.
2. Beginning January 1, 2001, the City shall submit by December 31 of each year a report that identifies the number of lead water service lines replaced in the previous 12 months, and specify the number which were owned by the City and the number owned other than by the City, until it has completed its lead water service replacement program in accordance with Section 13.18, Madison General Ordinances, and this Consent Order. The December 31, 2001 report also shall indicate the total number of lead water service lines located within the City as of that date, and specify the number owned by the City and the number owned other than by the City.
3. After completing its lead water service replacement program, the City shall collect a representative set of compliance samples, as specified in s. NR 809.547, Wis. Adm. Code, within the area where lead water service lines were replaced. The City shall submit all results from the sampling program to the Department within 30 days after receiving results from the laboratory.
4. The Department shall determine whether corrosion control treatment has been optimized, as required by s. NR 809.542(2), Wis. Adm. Code, after evaluating the effectiveness of lead water service line replacement. The Department shall deem the water system to have optimized corrosion control treatment, as provided in s. NR 809.542(2)(c), Wis. Adm. Code, if the sampling program demonstrates for 2 consecutive 6-month monitoring periods that the difference between the 90<sup>th</sup> percentile tap water lead level computed under s. NR 809.541(3)(c) and the highest source water lead concentrations is less than 5 ug/L.



5. Within 90 days after this Order is signed, the City shall submit to the Department for approval, and upon approval shall promptly implement, a lead public education program targeted at customers who have lead water service lines. The program shall include mass mailings, public service announcements, press releases, or other educational efforts approved by both parties, and shall continue through the course of the lead water service line replacement program required by sec. 13.18, Madison General Ordinances, and this Consent Order.
6. The City shall complete the entire lead water service line replacement program required by this Consent Order and s. 13.18, Madison General Ordinances, including any actions for which exceptions and extensions were granted under s. 13.18(8) of such Ordinance, no later than January 1, 2011. If the City is unable to complete any part of the lead water service line replacement program by that date, or fails to comply with any deadline established by this Consent Order or such Ordinance, the Department may issue another order specifying an alternative method for corrosion control optimization.
7. With the exception of Section 7, Financing of Replacement, the City may not amend Madison General Ordinance 13.18 without written consent of the Department, which consent shall not be unreasonably withheld on amendments which are consistent with this Consent Order.

#### WAIVER AND STIPULATION

The City of Madison stipulates to the issuance of this Consent Order and hereby waives further notice and statutory rights to demand a hearing before the Department of Natural Resources regarding the foregoing Findings of Fact, Conclusions of Law and Consent Order under s. 281.19(8), Stats., [formerly numbered s. 144.025(7), Stats.], or under any other provision of law and waives its rights to challenge this Consent Order in circuit court under ss. 227.52 and 227.53, Wis. Stats., or any other provision of law. The City of Madison further stipulates and agrees that the Consent Order is effective and enforceable after being signed by the parties and may be enforced in accordance with ss. 299.95 and 299.97, Stats. [formerly numbered ss. 144.98 and 144.99, Stats.]. Nothing in this Order shall be construed as an admission on the part of the City of Madison, for any purpose other than for an action taken for failure to comply with the terms of this Order. This stipulation and waiver does not affect the right of the City of Madison to assert any equitable or legal defense or to challenge the Department's interpretation or application of this Order; however, the City does hereby consent to and agree not to contest the Department's jurisdiction to issue this Consent Order or to enforce its terms.

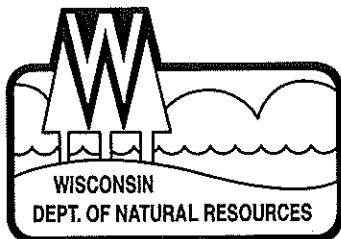
The undersigned certify that they are authorized to execute such Consent Order, Waiver, and Stipulation.

STATE OF WISCONSIN DEPARTMENT OF NATURAL RESOURCES, For the Secretary

By:

Steve Sisbach  
Brenda B. Hagman, Director  
Office of Environmental Enforcement  
Bureau of Law Enforcement

12-18-00  
Date



**State of Wisconsin \ DEPARTMENT OF NATURAL RESOURCES**

Jim Doyle, Governor  
Scott Hassett, Secretary

101 S. Webster St.  
Box 7921  
Madison, Wisconsin 53707-7921  
Telephone 608-266-2621  
FAX 608-267-3579  
TTY 608-267-6897

February 17, 2010

Mr. Tom Heikkinen, General Manager  
Madison Water Utility  
119 E. Olin Avenue  
Madison, WI 53713-1431

Casetrack # 2000-COEE-001-A  
FID# 26701048

SUBJECT: Amended Consent Order for Lead Service Line Replacement

Dear Mr. Heikkinen,

Enclosed is one original copy of amended Consent Order number 2000-COEE-001-A, regarding actions to reduce lead in the City of Madison public water supply system.

The amended Consent Order is now in effect and enforceable. The Department looks forward to working with you to meet the compliance commitments established in this agreement.

If you have any questions on this matter, please contact Pam Kober at (608) 275-3306.

Sincerely,

Steven L. Sisbach, Section Chief  
Environmental Enforcement & Emergency Management  
Bureau of Law Enforcement

c: Jill Jonas – DG/2  
Judy Ohm – LS/8  
Pam Kober – SCR  
Tom Stunkard - SCR  
Doug DeMaster, Madison Water Utility, 119 E. Olin Avenue, Madison, WI 53713-1431

In the Matter of the Optimal Corrosion )  
Treatment of the Public Water Supply of the )  
City of Madison in Dane County, Wisconsin ) Case No.: 2000-COEE-001-A

The Department and City agree to the following Addendum to Consent Order 2000-COEE-001:

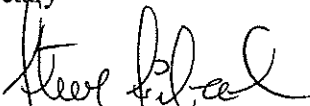
1. The City shall continue the replacement of the City-side lead water service lines in accordance with Section 13.18, Madison General Ordinances and according to a schedule that will complete such replacement by January 1, 2012. The Department may require the City to submit for Department approval a schedule setting dates by which the City shall meet interim lead water service line replacement goals. The Department agrees that it will not require an interim schedule so long as the City is undertaking reasonable efforts to comply with the January 1, 2012 completion date. The City agrees to submit an interim schedule upon reasonable request by the Department and to comply with the schedule as approved by the Department.
2. Beginning in 2011, the City shall collect a representative set of compliance samples, as specified in NR 809.547, Wis. Adm. Code, within the area where lead water service lines were replaced. The City shall submit all results from the sampling program to the Department within 30 days after receiving results from the laboratory.
3. The City shall complete the entire lead water service line replacement program required by this Consent Order and s. 13.18, Madison General Ordinances, including any actions for which exceptions and extensions were granted under s. 13.18(8) of such Ordinance, no later than January 1, 2012. If the City is unable to complete any part of the lead water service line replacement program by that date, or fails to comply with any deadline established by this Consent Order or such Ordinance, the Department may issue another order specifying an alternative method for corrosion control optimization.
4. The City is not out of compliance with paragraph 6 of Consent Order 2000-COEE-001 if any of the following occurs:
  - a. A lead water service line owned by the City is discovered after January 1, 2012, and the City replaces the line no later than 30 days after it is discovered.

- b. A lead water service line not owned by the City is discovered after January 1, 2012, and the City requires the owner of the line to replace the line no later than 12 months after it is discovered.
  - c. A lead water service line owned partly by the City and partly by another owner is discovered after January 1, 2012, and the City replaces its portion of the line no later than 12 months after it is discovered and the City requires the owner of the other portion of the line to replace that portion of the line no later than 12 months after it is discovered.
  - d. A lead water service line not owned by the City remains in service after January 1, 2012, if the City has provided the current owner or last-known owner of the line with at least two notices and the City is pursuing legal action to require that person to replace or remove the line.
  - e. A lead water service line, owned by the City or another owner, remains temporarily connected to the City water system, as long as the line is rendered physically unusable, such as by filling the shutoff valve box with concrete, and provided that the line shall never be used and shall be physically disconnected from the City water system as soon as street construction in the vicinity allows access to the line.
5. The City shall take the following steps to determine whether additional lead water service lines exist and need to be replaced or removed:
- a. Require statements from property owners of properties constructed before 1928 in areas of the City where the City Water Utility provided service prior to 1931 and require replacement of lead water service lines for those properties.
  - b. Establish criteria to identify properties that may have lead water service lines, including but not limited to, the age of the building, the age of the water distribution system in the area serving the building, and observations of City water utility staff, property owners and property managers, licensed plumbers and others knowledgeable with the water service lines.
  - c. The City may require property owners to excavate if there is a reasonable basis to suspect that the property is served by lead water service lines.


#### **WAIVER AND STIPULATION**

The City of Madison stipulates to the issuance of this Addendum to Consent Order and hereby waives further notice and statutory rights to demand a hearing before the Department of Natural Resources regarding the Addendum under s. 281.19(8), Stats., or under any other provision of law and waives its rights to challenge this Addendum in circuit court under ss. 227.52 and 227.53, Wis. Stats., or any other provision of law. The City of Madison further stipulates and agrees that the Addendum is effective and enforceable after being signed by the parties and may be enforced in accordance with ss. 299.95 and 299.97, Stats. Nothing in this Addendum shall be construed as an admission on the part of the City of Madison for any purpose other than for an action taken for failure to comply with the terms of this Addendum. The undersigned certify that they are authorized to execute such Consent Order, Waiver, and Stipulation.

STATE OF WISCONSIN, DEPARTMENT OF NATURAL RESOURCES,  
For the Secretary

By:  2-17-10  
Steven L. Sisbach, Section Chief Date  
Environmental Enforcement & Emergency Management  
Bureau of Law Enforcement

CITY OF MADISON

By:  2-10-10  
Tom Heikkinen, General Manager Date  
Madison Water Utility

## Appendix B: Original 1992 Lead and Copper Rule Sampling Sites



**A. 1992 Compliance Sites that *ARE* included in the proposed 2011 Compliance Site sample pool and never had a lead service (37)**

Constructed after lead no longer used (lead solder likely)

Sample Date	Field No.	Parcel No.	Address
4/3/1992	508	071003108092	5054 Piccadilly Dr
4/22/1992	505	060802408141	5 Lancaster Ct
5/6/1992	504	070836307079	6 Park Crest Ct
4/6/1992	500	060802404107	2909 Greenway Trl
4/7/1992	499	071003108125	5110 Piccadilly Dr
4/30/1992	496	060904113276	3041 Irvington Way
3/23/1992	493	071003108133	5114 Piccadilly Dr
4/14/1992	492	080935107064	517 Muir Dr
4/8/1992	491	070823303030	7881 E Oakbrook Cir
4/27/1992	490	060802405056	7109 Lancaster Ln
4/22/1992	488	070814417098	7113 Harvest Hill Rd
4/8/1992	486	060802402094	3045 Greenway Trl
4/10/1992	485	071003417188	5105 Stage House Trl
4/16/1992	484	080924304069	1205 Menomonie Ln
4/6/1992	483	070814410109	7009 Harvest Hill Rd
4/17/1992	480	070814407081	14 Glenside Cir
4/20/1992	479	071015405048	2034 Vondron Rd
4/10/1992	476	070823304343	7830 W Oakbrook Cir
4/16/1992	478	071003407212	125 Coach House Dr
3/26/1992	475	071003108117	5106 Piccadilly Dr
4/15/1992	472	060802404082	2901 Greenway Trl
3/26/1992	471	070823304244	7870 W Oakbrook Cir
4/6/1992	470	060802408092	25 Lancaster Ct
4/14/1992	466	071003107177	5101 Piccadilly Dr
4/21/1992	464	070813309022	22 E Spyglass Ct
4/14/1992	462	071015406103	5018 Stonehaven Dr
5/8/1992	465	081021416062	4005 Tomscot Trl
4/14/1992	461	071003417170	5101 Stage House Trl
3/23/1992	457	060802403034	7017 Carnwood Rd
4/17/1992	452	070814411115	17 S Strathfield Cir
4/14/1992	451	070813309056	2 E Spyglass Ct
3/30/1992	453	070813304254	6813 Harvest Hill Rd
3/30/1992	456	070813304048	6901 Harvest Hill Rd
4/17/1992	449	070823304278	7858 W Oakbrook Cir
4/27/1992	455	070823303048	7877 E Oakbrook Cir
4/14/1992	448	071003108076	5046 Piccadilly Dr
3/26/1992	450	071003107151	5109 Piccadilly Dr

**B. 1992 Compliance Sites that are *NOT* included in the proposed 2011 Compliance Site sample pool: construction year is NOT 1983 or 1984 (9)**

Sample Date	Field No.	Parcel No.	Address	Construction Year
5/4/1992	494	060802402242	3006 Greenway Trl	1985
5/4/1992	489	071021225109	709 Woodlawn Dr	1982
4/9/1992	482	071003402072	125 St Albans Ave	1978
3/20/1992	481	071015405262	14 Hollybrook Ct	1981
4/1/1992	473	070814415042	6 N Strathfield Cir	1980
4/23/1992	468	070823304096	7958 W Oakbrook Cir	1985
3/23/1992	463	070813304171	5 W Spyglass Ct	1982
4/16/1992	454	071003410132	218 St Albans Ave	1982
5/4/1992	447	081021412169	6 Granby Cir	1982

**C. 1992 Compliance Sites that are *NOT* included in the proposed 2011 Compliance Site sample pool: lead service has been replaced (54)**

Sample Date	Field No.	Parcel No.	Address
4/21/1992	546	070926107082	1103 Lawrence St
4/9/1992	545	070912404468	422 Marston Ave
4/9/1992	544	071007201181	1614 Rutledge St
4/14/1992	543	070922335174	609 Leonard St
4/9/1992	542	071006401146	118 Talmadge St
4/3/1992	541	070921417113	2237 Fox Ave
4/14/1992	540	071006204293	2309 Superior St
4/9/1992	539	071005301090	133 Talmadge St
4/13/1992	538	070922234079	1715 Chadbourne Ave
4/8/1992	537	070926117065	621 South Shore Dr
4/3/1992	536	071006429106	2218 Center Ave
4/6/1992	535	070921417064	2215 Fox Ave
4/2/1992	533	070912405143	429 Sidney St
4/22/1992	532	070913216044	916 Castle Pl
4/13/1992	534	071006404158	174 Dunning St
4/8/1992	531	070921417270	2254 Keyes Ave
4/15/1992	530	070921419078	2437 Fox Ave
4/2/1992	528	070923408318	710 W Brittingham Pl
4/21/1992	529	071007202163	422 Clemons Ave
4/1/1992	525	070921416157	2214 Fox Ave
4/8/1992	524	070921416066	2250 Fox Ave
3/31/1992	523	071006211131	2306 Upham St
4/3/1992	526	071007116299	1854 Jenifer St
4/21/1992	527	071007201199	1618 Rutledge St
3/31/1992	522	071007112073	1833 Spaight St
4/20/1992	521	070921103192	2610 Stevens St
5/4/1992	520	070921417189	2263 Fox Ave
4/10/1992	519	071006119012	2441 E Mifflin St
4/14/1992	518	070912404252	329 N Baldwin St
4/3/1992	517	071006204300	2307 Superior St
4/22/1992	516	070922428135	1522 Vilas Ave
4/3/1992	515	070928116156	2405 Monroe St
3/23/1992	514	070928117394	825 Terry Pl
4/3/1992	513	071007104129	2150 Lakeland Ave
4/6/1992	512	070921416173	2206 Fox Ave
4/23/1992	511	070921416165	2210 Fox Ave
4/9/1992	510	070921416115	2230 Fox Ave
4/22/1992	509	070922337071	2120 Jefferson St
4/3/1992	507	070921416149	2218 Fox Ave
4/14/1992	506	071005336089	303 Hudson Ave
3/23/1992	503	070922337047	2115 Madison St
3/30/1992	502	071006122221	2646 E Dayton St
3/23/1992	501	070921416090	2234 Fox Ave
3/30/1992	498	070921417139	2247 Fox Ave
4/1/1992	497	070921109091	2225 Kendall Ave
4/2/1992	495	071005224169	57 Corry St
4/7/1992	487	071006302162	205 N Third St
4/10/1992	477	070921416074	2246 Fox Ave
3/23/1992	474	070923409259	152 Rodney Ct
4/20/1992	469	070931211084	1114 Sunridge Dr
3/23/1992	467	071005221214	38 Dixon St
4/1/1992	459	070921416016	2400 Fox Ave
4/1/1992	458	070928314239	706 Seneca Pl
3/23/1992	460	071006128427	2622 E Johnson St

## Appendix C: Tier 1 Sites for 2011 Lead and Copper Rule Sampling

House Num	Street Dir	Street Name	Street Type	Year Built	Parcel Number	Neighborhood
104	S	Franklin	St	1984	070913334028	Central
106	S	Franklin	St	1984	070913334036	Central
108	S	Franklin	St	1984	070913334044	Central
110	S	Franklin	St	1984	070913334052	Central
112	S	Franklin	St	1984	070913334060	Central
114	S	Franklin	St	1984	070913334078	Central
116	S	Franklin	St	1984	070913334086	Central
118	S	Franklin	St	1984	070913334094	Central
120	S	Franklin	St	1984	070913334101	Central
5305		Brookshire	Ln	1984	071003411023	East
5317		Brookshire	Ln	1983	071003411057	East
5402		Brookshire	Ln	1983	071003412055	East
5414		Brookshire	Ln	1983	071003412021	East
121		Coach House	Dr	1983	071003407204	East
125		Coach House	Dr	1983	071003407212	East
229		Coach House	Dr	1984	071003407303	East
233		Coach House	Dr	1984	071003407311	East
313		Coach House	Dr	1983	071003407353	East
317		Coach House	Dr	1983	071003407361	East
5109		Cottage Grove	Rd	1983	071010415240	East
4541		McCann	Rd	1983	071003214162	East
4542		McCann	Rd	1984	071003213213	East
5021		Milwaukee	St	1983	071003418144	East
5025		Milwaukee	St	1983	071003418136	East
5101		Milwaukee	St	1983	071003418128	East
5105		Milwaukee	St	1983	071003418110	East
5109		Milwaukee	St	1983	071003418102	East
5113		Milwaukee	St	1983	071003418095	East
5117		Milwaukee	St	1983	071003418087	East
5121		Milwaukee	St	1983	071003418079	East
5125		Milwaukee	St	1983	071003418061	East
5201		Milwaukee	St	1983	071003418053	East
5205		Milwaukee	St	1984	071003418045	East
5209		Milwaukee	St	1984	071003418037	East
5213		Milwaukee	St	1984	071003418029	East
5217		Milwaukee	St	1984	071003418011	East
5021		Piccadilly	Dr	1984	071003107250	East
5025		Piccadilly	Dr	1984	071003107242	East
5029		Piccadilly	Dr	1983	071003107234	East
5030		Piccadilly	Dr	1984	071003108034	East
5033		Piccadilly	Dr	1984	071003107226	East
5037		Piccadilly	Dr	1984	071003107218	East
5038		Piccadilly	Dr	1984	071003108050	East
5041		Piccadilly	Dr	1984	071003107200	East
5042		Piccadilly	Dr	1984	071003108068	East
5046		Piccadilly	Dr	1983	071003108076	East
5049		Piccadilly	Dr	1984	071003107185	East
5050		Piccadilly	Dr	1984	071003108084	East
5054		Piccadilly	Dr	1983	071003108092	East
5101		Piccadilly	Dr	1983	071003107177	East
5105		Piccadilly	Dr	1983	071003107169	East
5106		Piccadilly	Dr	1984	071003108117	East
5109		Piccadilly	Dr	1983	071003107151	East
5110		Piccadilly	Dr	1983	071003108125	East
5113		Piccadilly	Dr	1983	071003107143	East
5114		Piccadilly	Dr	1983	071003108133	East
5118		Piccadilly	Dr	1983	071003108141	East
105		St Albans	Ave	1983	071003402022	East
113		St Albans	Ave	1983	071003402048	East
210		St Albans	Ave	1983	071003410158	East
5002		Stage House	Trl	1984	071003418160	East
5005		Stage House	Trl	1984	071003417146	East
5009		Stage House	Trl	1984	071003417154	East
5010		Stage House	Trl	1984	071003418186	East
5014		Stage House	Trl	1984	071003418194	East
5101		Stage House	Trl	1984	071003417170	East
5102		Stage House	Trl	1984	071003418201	East
5105		Stage House	Trl	1984	071003417188	East
5106		Stage House	Trl	1984	071003418219	East
5109		Stage House	Trl	1984	071003417196	East

5113		Stage House	Trl	1984	071003417203	East
5138		Stage House	Trl	1984	071003418285	East
5401		Sudbury	Way	1984	071003412170	East
4848		Violet	Ln	1984	071003207159	East
4857		Violet	Ln	1983	071003208149	East
4913		Violet	Ln	1984	071003208107	East
4914		Violet	Ln	1983	071003207216	East
4917		Violet	Ln	1984	071003208090	East
13		Esther	Ct	1983	071003213172	East
17		Esther	Ct	1984	071003213164	East
5610	E	Buckeye	Rd	1983	071014202304	East Buckeye
5614	E	Buckeye	Rd	1983	071014202312	East Buckeye
5618	E	Buckeye	Rd	1983	071014202320	East Buckeye
4934		Camilla	Rd	1984	071015110267	East Buckeye
1625		Deerwood	Dr	1984	071015204284	East Buckeye
1721		Droster	Rd	1983	071014201166	East Buckeye
1946		Ellen	Ave	1983	071015119334	East Buckeye
1730		Grafton	Rd	1983	071014201182	East Buckeye
5606		Kalas	St	1984	071011302090	East Buckeye
5609		Kalas	St	1983	071011304054	East Buckeye
5626		Kalas	St	1983	071011302149	East Buckeye
5006		Pebblebrook	Dr	1983	071015405189	East Buckeye
5010		Pebblebrook	Dr	1983	071015405197	East Buckeye
5014		Pebblebrook	Dr	1983	071015405204	East Buckeye
5018		Pebblebrook	Dr	1983	071015405212	East Buckeye
5021		Pebblebrook	Dr	1984	071015407078	East Buckeye
5022		Pebblebrook	Dr	1983	071015405220	East Buckeye
5029		Pebblebrook	Dr	1983	071015407052	East Buckeye
5101		Pebblebrook	Dr	1983	071015407044	East Buckeye
5105		Pebblebrook	Dr	1983	071015407036	East Buckeye
5106		Pebblebrook	Dr	1983	071015405311	East Buckeye
5109		Pebblebrook	Dr	1983	071015407028	East Buckeye
1		Sandlewood	Cir	1984	071015407135	East Buckeye
5		Sandlewood	Cir	1984	071015407143	East Buckeye
6		Sandlewood	Cir	1984	071015406153	East Buckeye
9		Sandlewood	Cir	1984	071015407151	East Buckeye
18		Sandlewood	Cir	1983	071015406179	East Buckeye
1		Stacy	Ln	1983	071010415191	East Buckeye
17		Stacy	Ln	1984	071010415175	East Buckeye
5001		Stonehaven	Dr	1983	071015405171	East Buckeye
5010		Stonehaven	Dr	1984	071015406129	East Buckeye
5014		Stonehaven	Dr	1984	071015406111	East Buckeye
5017		Stonehaven	Dr	1983	071015405163	East Buckeye
5018		Stonehaven	Dr	1983	071015406103	East Buckeye
5022		Stonehaven	Dr	1983	071015406096	East Buckeye
5029		Stonehaven	Dr	1983	071015405139	East Buckeye
5030		Stonehaven	Dr	1983	071015406070	East Buckeye
5117		Stonehaven	Dr	1983	071015405072	East Buckeye
1906		Vondron	Rd	1983	071015112164	East Buckeye
2034		Vondron	Rd	1983	071015405048	East Buckeye
2102		Vondron	Rd	1983	071015405030	East Buckeye
2106		Vondron	Rd	1983	071015405022	East Buckeye
5008		Buckeye	Rd	1983	071016103188	East Buckeye
5010		Buckeye	Rd	1983	071016103196	East Buckeye
101	E	Lakeview	Ave	1984	071016108013	East Buckeye
5		Hollybrook	Ct	1983	071015405296	East Buckeye
6		La Crescenta	Cir	1983	071015403133	East Buckeye
7		La Crescenta	Cir	1983	071015403307	East Buckeye
14		La Crescenta	Cir	1983	071015403159	East Buckeye
17		La Crescenta	Cir	1984	071015403282	East Buckeye
21		La Crescenta	Cir	1984	071015403274	East Buckeye
33		La Crescenta	Cir	1983	071015403240	East Buckeye
37		La Crescenta	Cir	1984	071015403232	East Buckeye
2941		Barlow	St	1983	070921210228	Near West
3341		Gregory	St	1984	070928223018	Near West
138		Larkin	St	1984	070921307116	Near West
462	S	Owen	Dr	1983	070929112278	Near West
4725		Regent	St	1983	070920213190	Near West
5310		Shawano	Ter	1983	070919410294	Near West
4405		American Ash	Dr	1984	080926112452	North
4409		American Ash	Dr	1984	080926112444	North

4413	American Ash	Dr	1984	080926112436	North
4414	American Ash	Dr	1983	080926113096	North
4506	American Ash	Dr	1984	080926113070	North
4518	American Ash	Dr	1984	080926113046	North
4702	American Ash	Dr	1984	080926110323	North
4714	American Ash	Dr	1984	080926110357	North
1405	Burning Wood	Way	1983	080924102083	North
5526	Comanche	Way	1984	080924104071	North
5522	Manitowish	Way	1983	080924105095	North
1510	Mayfield	Ln	1984	080925403109	North
917	Menomonie	Ln	1984	080924304233	North
1205	Menomonie	Ln	1983	080924304069	North
413	Muir	Dr	1984	080935107113	North
517	Muir	Dr	1984	080935107064	North
4501	Texas	Trl	1983	080925416136	North
913	Troy	Dr	1983	080936203019	North
4501	White Aspen	Rd	1983	080926113145	North
4505	White Aspen	Rd	1984	080926113153	North
4513	White Aspen	Rd	1984	080926113179	North
14	Norway Maple	Cir	1984	080926112246	North
4102	David	Rd	1983	081028110170	Northeast
3214	Lotheville	Rd	1984	081021402251	Northeast
3502	Old Gate	Rd	1984	081021416129	Northeast
3506	Portage	Rd	1984	081021413191	Northeast
3302	Sunbrook	Rd	1983	081021405180	Northeast
3310	Sunbrook	Rd	1983	081021405164	Northeast
3406	Sunbrook	Rd	1983	081021405148	Northeast
4001	Tomscot	Trl	1984	081021416070	Northeast
4005	Tomscot	Trl	1984	081021416062	Northeast
4006	Tomscot	Trl	1984	081021416096	Northeast
4014	Tomscot	Trl	1984	081021416111	Northeast
4017	Tomscot	Trl	1984	081021416038	Northeast
4021	Tomscot	Trl	1984	081021416020	Northeast
4102	Tomscot	Trl	1984	081021413133	Northeast
4126	Tomscot	Trl	1984	081021413183	Northeast
1	Granby	Cir	1984	081021412234	Northeast
9	Granby	Cir	1984	081021412226	Northeast
10	Granby	Cir	1983	081021412177	Northeast
13	Granby	Cir	1984	081021412218	Northeast
14	Granby	Cir	1983	081021412185	Northeast
17	Granby	Cir	1984	081021412200	Northeast
18	Granby	Cir	1984	081021412193	Northeast
1852	Baird	St	1983	070926415196	South
3206	Heatherdell	Ln	1984	060904102310	South
3029	Irvington	Way	1983	060904113292	South
3033	Irvington	Way	1983	060904113284	South
3041	Irvington	Way	1983	060904113276	South
4350	Windflower	Way	1983	060905102012	South
2606	Waunona	Way	1984	071030202239	South
5102	Meinders	Rd	1983	071027400911	South
5106	Meinders	Rd	1983	071027400911	South
706	Woodlawn	Dr	1984	071021224094	South
717	Woodlawn	Dr	1983	071021225084	South
809	Woodlawn	Dr	1983	071021225050	South
6913	Carnwood	Rd	1984	060801305091	Southwest
6918	Carnwood	Rd	1984	060801302253	Southwest
7009	Carnwood	Rd	1984	060802403018	Southwest
7010	Carnwood	Rd	1983	060802404157	Southwest
7014	Carnwood	Rd	1983	060802404149	Southwest
7017	Carnwood	Rd	1983	060802403034	Southwest
7021	Carnwood	Rd	1983	060802403042	Southwest
7102	Carnwood	Rd	1983	060802404016	Southwest
7005	Chelsea	St	1983	060802402010	Southwest
7009	Chelsea	St	1983	060802402028	Southwest
7010	Chelsea	St	1984	060802403084	Southwest
7013	Chelsea	St	1983	060802402036	Southwest
7014	Chelsea	St	1983	060802403076	Southwest
7018	Chelsea	St	1983	060802403068	Southwest
7022	Chelsea	St	1983	060802403050	Southwest
3002	Greenway	Trl	1983	060802402250	Southwest
3021	Greenway	Trl	1983	060802402044	Southwest

5706	Hammersley	Rd	1984	070931212313	Southwest
5910	Hempstead	Rd	1984	070931210119	Southwest
6505	Jacobs	Way	1983	070836307293	Southwest
3013	Jason	Pl	1984	060801307089	Southwest
5914	Piping Rock	Rd	1983	070931211018	Southwest
5829	Suffolk	Rd	1984	070931206085	Southwest
1141	Sunridge	Dr	1983	070931206150	Southwest
6605	Sutton	Rd	1984	070836118070	Southwest
7001	Gladstone	Dr	1984	060802107058	Southwest
7002	Gladstone	Dr	1984	060802106266	Southwest
7010	Lancaster	Ln	1983	060802406012	Southwest
7101	Lancaster	Ln	1984	060802405030	Southwest
7102	Lancaster	Ln	1983	060802407028	Southwest
7105	Lancaster	Ln	1983	060802405048	Southwest
7109	Lancaster	Ln	1983	060802405056	Southwest
7005	Lindfield	Rd	1984	060802106133	Southwest
7006	Lindfield	Rd	1984	060802109088	Southwest
2405	Muir Field	Rd	1984	060802106117	Southwest
2725	Muir Field	Rd	1984	060802407036	Southwest
2802	Muir Field	Rd	1983	060802408159	Southwest
7117	Pagham	Dr	1984	060802101050	Southwest
7121	Pagham	Dr	1984	060802101068	Southwest
7122	Pagham	Dr	1984	060802101084	Southwest
6401	Putnam	Rd	1983	060801313010	Southwest
3013	Shefford	Dr	1984	060801308061	Southwest
3025	Shefford	Dr	1984	060801308037	Southwest
2306	Whitlock	Rd	1983	060802109012	Southwest
2309	Whitlock	Rd	1983	060802108014	Southwest
2310	Whitlock	Rd	1983	060802109020	Southwest
2318	Whitlock	Rd	1983	060802109046	Southwest
2321	Whitlock	Rd	1983	060802108022	Southwest
2322	Whitlock	Rd	1983	060802109054	Southwest
2329	Whitlock	Rd	1983	060802108030	Southwest
2330	Whitlock	Rd	1983	060802109070	Southwest
2333	Whitlock	Rd	1983	060802108048	Southwest
2401	Whitlock	Rd	1983	060802108056	Southwest
2402	Whitlock	Rd	1984	060802106141	Southwest
2405	Whitlock	Rd	1983	060802108064	Southwest
2406	Whitlock	Rd	1983	060802106159	Southwest
2409	Whitlock	Rd	1983	060802108072	Southwest
2410	Whitlock	Rd	1983	060802106167	Southwest
2413	Whitlock	Rd	1983	060802108080	Southwest
2414	Whitlock	Rd	1983	060802106175	Southwest
2417	Whitlock	Rd	1983	060802108098	Southwest
2418	Whitlock	Rd	1983	060802106183	Southwest
2421	Whitlock	Rd	1983	060802108105	Southwest
2422	Whitlock	Rd	1983	060802106191	Southwest
2502	Whitlock	Rd	1983	060802106208	Southwest
2506	Whitlock	Rd	1983	060802106216	Southwest
2510	Whitlock	Rd	1984	060802106224	Southwest
2514	Whitlock	Rd	1984	060802106232	Southwest
2602	Whitlock	Rd	1983	060802106240	Southwest
2606	Whitlock	Rd	1983	060802106258	Southwest
2609	Whitlock	Rd	1983	060802108189	Southwest
2613	Whitlock	Rd	1984	060802108197	Southwest
2701	Whitlock	Rd	1984	060802108204	Southwest
2705	Whitlock	Rd	1984	060802108212	Southwest
2709	Whitlock	Rd	1983	060802108220	Southwest
2710	Whitlock	Rd	1984	060802107040	Southwest
2713	Whitlock	Rd	1983	060802108238	Southwest
2714	Whitlock	Rd	1984	060802107032	Southwest
2717	Whitlock	Rd	1984	060802108246	Southwest
2718	Whitlock	Rd	1984	060802107024	Southwest
2721	Whitlock	Rd	1983	060802108254	Southwest
2722	Whitlock	Rd	1984	060802107016	Southwest
2726	Whitlock	Rd	1983	060802407010	Southwest
2901	Greenway	Trl	1983	060802404082	Southwest
2905	Greenway	Trl	1983	060802404090	Southwest
2906	Greenway	Trl	1983	060802404066	Southwest
2909	Greenway	Trl	1983	060802404107	Southwest
2910	Greenway	Trl	1983	060802404058	Southwest

2914		Greenway	Trl	1983	060802404040	Southwest
2917		Greenway	Trl	1983	060802404123	Southwest
2918		Greenway	Trl	1983	060802404032	Southwest
2922		Greenway	Trl	1983	060802404024	Southwest
3026		Greenway	Trl	1983	060802402193	Southwest
3029		Greenway	Trl	1984	060802402052	Southwest
3033		Greenway	Trl	1983	060802402060	Southwest
3034		Greenway	Trl	1984	060802402177	Southwest
3038		Greenway	Trl	1983	060802402169	Southwest
3045		Greenway	Trl	1984	060802402094	Southwest
3049		Greenway	Trl	1983	060802402101	Southwest
3050		Greenway	Trl	1983	060802402143	Southwest
5		Jacobs	Ct	1984	070836307277	Southwest
9		Jacobs	Ct	1984	070836307269	Southwest
10		Jason	Cir	1983	060801307055	Southwest
6		Park Crest	Ct	1984	070836307079	Southwest
14		Wichita	Ct	1984	060802409230	Southwest
5		Georgetown	Ct	1983	070836207138	Southwest
6		Georgetown	Ct	1983	070836207097	Southwest
7		Georgetown	Ct	1983	070836207386	Southwest
8		Georgetown	Ct	1983	070836207485	Southwest
9		Georgetown	Ct	1983	070836207120	Southwest
10		Georgetown	Ct	1984	070836207104	Southwest
11		Georgetown	Ct	1983	070836207518	Southwest
12		Georgetown	Ct	1984	070836207443	Southwest
14		Georgetown	Ct	1984	070836207451	Southwest
16		Georgetown	Ct	1984	070836207112	Southwest
12		New Berm	Ct	1983	070836207378	Southwest
2		Lancaster	Ct	1983	060802408018	Southwest
5		Lancaster	Ct	1983	060802408141	Southwest
6		Lancaster	Ct	1984	060802408026	Southwest
9		Lancaster	Ct	1983	060802408133	Southwest
10		Lancaster	Ct	1983	060802408034	Southwest
14		Lancaster	Ct	1984	060802408042	Southwest
25		Lancaster	Ct	1983	060802408092	Southwest
26		Lancaster	Ct	1984	060802408076	Southwest
2		Crossbridge	Ct	1983	070823306175	West
6		Crossbridge	Ct	1984	070823306183	West
14		Crossbridge	Ct	1983	070823306208	West
22		Crossbridge	Ct	1983	070823306224	West
26		Crossbridge	Ct	1983	070823306232	West
6805		Harvest Hill	Rd	1984	070813304238	West
6810		Harvest Hill	Rd	1983	070813307167	West
6813		Harvest Hill	Rd	1984	070813304254	West
6814		Harvest Hill	Rd	1983	070813307175	West
6818		Harvest Hill	Rd	1984	070813307183	West
6901		Harvest Hill	Rd	1984	070813304048	West
6905		Harvest Hill	Rd	1984	070813304030	West
7005		Harvest Hill	Rd	1983	070814410092	West
7009		Harvest Hill	Rd	1983	070814410109	West
7010		Harvest Hill	Rd	1984	070814412022	West
7113		Harvest Hill	Rd	1983	070814417098	West
6		Haverhill	Cir	1983	070814416024	West
17		Haverhill	Cir	1983	070814415092	West
21		Haverhill	Cir	1983	070814415109	West
22		Haverhill	Cir	1983	070814416066	West
26		Haverhill	Cir	1983	070814416074	West
29		Haverhill	Cir	1983	070814415125	West
2		Oak Glen	Ct	1983	070823306315	West
5		Oak Glen	Ct	1984	070823307024	West
6		Oak Glen	Ct	1984	070823306307	West
9		Oak Glen	Ct	1984	070823307032	West
10		Oak Glen	Ct	1984	070823306290	West
13		Oak Glen	Ct	1984	070823307040	West
17		Oak Glen	Ct	1983	070823307058	West
21		Oak Glen	Ct	1984	070823307066	West
22		Oak Glen	Ct	1984	070823306266	West
25		Oak Glen	Ct	1983	070823307074	West
7801	E	Oakbrook	Cir	1984	070823303220	West
7813	E	Oakbrook	Cir	1984	070823303197	West
7821	E	Oakbrook	Cir	1984	070823303171	West



7826	E	Oakbrook	Cir	1983	070823307248	West
7841	E	Oakbrook	Cir	1984	070823303139	West
7857	E	Oakbrook	Cir	1984	070823303098	West
7873	E	Oakbrook	Cir	1983	070823303056	West
7877	E	Oakbrook	Cir	1983	070823303048	West
7881	E	Oakbrook	Cir	1984	070823303030	West
7885	E	Oakbrook	Cir	1984	070823303022	West
7909	W	Oakbrook	Cir	1984	070823305028	West
7913	W	Oakbrook	Cir	1984	070823305036	West
7929	W	Oakbrook	Cir	1984	070823305078	West
7941	W	Oakbrook	Cir	1984	070823305101	West
7953	W	Oakbrook	Cir	1984	070823305135	West
7970	W	Oakbrook	Cir	1984	070823304062	West
7986	W	Oakbrook	Cir	1984	070823304020	West
6713		Old Sauk	Rd	1983	070824220126	West
6714		Old Sauk	Rd	1984	070813301010	West
810		Pebble Beach	Dr	1983	070813307133	West
13		Ramsgate	Cir	1984	070814423079	West
2		Sandy	Ct	1983	070823305151	West
6		Sandy	Ct	1983	070823305169	West
9		Sandy	Ct	1983	070823306141	West
10		Sandy	Ct	1983	070823305177	West
13		Sandy	Ct	1983	070823306133	West
14		Sandy	Ct	1983	070823305185	West
18		Sandy	Ct	1984	070823305193	West
22		Sandy	Ct	1983	070823305200	West
26		Sandy	Ct	1983	070823305218	West
29		Sandy	Ct	1983	070823306092	West
7313		Sawmill	Rd	1984	070814422021	West
7405		Sawmill	Rd	1984	070814403162	West
7414		Sawmill	Rd	1984	070814425017	West
1436	E	Skyline	Dr	1983	070813109068	West
2		Stonehedge	Ct	1983	070823305309	West
5		Stonehedge	Ct	1984	070823306026	West
9		Stonehedge	Ct	1984	070823306034	West
10		Stonehedge	Ct	1984	070823305284	West
16		Stonehedge	Ct	1984	070823305276	West
17		Stonehedge	Ct	1983	070823306050	West
18		Stonehedge	Ct	1984	070823305268	West
21		Stonehedge	Ct	1983	070823306068	West
25		Stonehedge	Ct	1984	070823306076	West
1009	N	Westfield	Rd	1983	070814404079	West
1102	N	Westfield	Rd	1984	070814425108	West
1110	N	Westfield	Rd	1984	070814425124	West
1114	N	Westfield	Rd	1984	070814425132	West
1122	N	Westfield	Rd	1984	070814426015	West
1126	N	Westfield	Rd	1984	070814426023	West
1130	N	Westfield	Rd	1984	070814426031	West
1134	N	Westfield	Rd	1984	070814426049	West
310		Acadia	Dr	1983	070824214038	West
7218		Colony	Dr	1983	070823117035	West
609		Everglade	Dr	1983	070824220019	West
25		Millstone	Rd	1983	070823412055	West
38		Millstone	Rd	1983	070823411057	West
206		Quarterdeck	Dr	1984	070824403144	West
601	N	Westfield	Rd	1984	070823110013	West
30		Winterset	Cir	1983	070823105121	West
7817	W	Oakbrook	Cir	1983	070823307305	West
7818	W	Oakbrook	Cir	1984	070823304377	West
7826	W	Oakbrook	Cir	1984	070823304351	West
7830	W	Oakbrook	Cir	1983	070823304343	West
7834	W	Oakbrook	Cir	1983	070823304335	West
7842	W	Oakbrook	Cir	1984	070823304319	West
7845	W	Oakbrook	Cir	1984	070823306018	West
7846	W	Oakbrook	Cir	1984	070823304301	West
7850	W	Oakbrook	Cir	1984	070823304294	West
7854	W	Oakbrook	Cir	1984	070823304286	West
7858	W	Oakbrook	Cir	1984	070823304278	West
7866	W	Oakbrook	Cir	1984	070823304252	West
7870	W	Oakbrook	Cir	1984	070823304244	West
5518		Belin	St	1984	070919217062	West

5526		Greening	Ln	1983	070918210166	West
1802		Hickory	Dr	1984	070918208038	West
1639		Norman	Way	1983	070918314059	West
1657		Norman	Way	1984	070918314116	West
6131		Old Middleton	Rd	1983	070813113027	West
5814		Taychopera	Rd	1984	070918206016	West
606		San Juan	Trl	1983	070824220085	West
610		San Juan	Trl	1983	070824220093	West
6226		Old Middleton	Rd	1984	070813103200	West
2		Apple Hill	Cir	1984	070814426198	West
6		Apple Hill	Cir	1984	070814426180	West
10		Apple Hill	Cir	1984	070814426172	West
13		Apple Hill	Cir	1984	070814426065	West
14		Apple Hill	Cir	1984	070814426164	West
18		Apple Hill	Cir	1984	070814426156	West
21		Apple Hill	Cir	1984	070814426073	West
22		Apple Hill	Cir	1984	070814426148	West
29		Apple Hill	Cir	1984	070814426081	West
30		Apple Hill	Cir	1984	070814426122	West
33		Apple Hill	Cir	1984	070814426099	West
34		Apple Hill	Cir	1984	070814426114	West
41		Apple Hill	Cir	1984	070814426106	West
6		Firestone	Ct	1984	070813304056	West
9		Firestone	Ct	1984	070813304329	West
6		Fiskdale	Cir	1983	070814413054	West
10		Fiskdale	Cir	1983	070814413046	West
14		Fiskdale	Cir	1984	070814413038	West
18		Fiskdale	Cir	1983	070814413020	West
21		Fiskdale	Cir	1983	070814412113	West
26		Fiskdale	Cir	1984	070814414044	West
29		Fiskdale	Cir	1983	070814412121	West
30		Fiskdale	Cir	1984	070814414036	West
34		Fiskdale	Cir	1983	070814414028	West
1		Glenside	Cir	1983	070814417064	West
14		Glenside	Cir	1983	070814407081	West
18		Glenside	Cir	1983	070814407099	West
22		Glenside	Cir	1983	070814407106	West
26		Glenside	Cir	1983	070814407114	West
5		Inverrary	Ct	1984	070813304262	West
9		Inverrary	Ct	1983	070813304270	West
14		Morningdale	Cir	1983	070814411032	West
17		Morningdale	Cir	1983	070814410068	West
25		Morningdale	Cir	1983	070814410042	West
29		Morningdale	Cir	1983	070814410034	West
2		Pinehurst	Cir	1983	070813307034	West
5		Pinehurst	Cir	1984	070813307117	West
13		Pinehurst	Cir	1983	070813307092	West
14		Pinehurst	Cir	1983	070813307050	West
18		Pinehurst	Cir	1983	070813307068	West
1 W		Spyglass	Ct	1984	070813304163	West
2 E		Spyglass	Ct	1983	070813309056	West
9 W		Spyglass	Ct	1983	070813304189	West
22 E		Spyglass	Ct	1983	070813309022	West
13 S		Strathfield	Cir	1983	070814411107	West
13 N		Strathfield	Cir	1983	070814414094	West
14 N		Strathfield	Cir	1983	070814415026	West
17 S		Strathfield	Cir	1983	070814411115	West
6		Wallingford	Cir	1984	070814425025	West
2		Windhaven	Cir	1984	070814423128	West
5		Windhaven	Cir	1984	070814423194	West
10		Windhaven	Cir	1984	070814423144	West
13		Windhaven	Cir	1984	070814423178	West
14		Windhaven	Cir	1984	070814423152	West
109		Horseshoe	Bnd	1983	070824209063	West
110		Horseshoe	Bnd	1983	070824218105	West
209		Saratoga	Cir	1983	070824221075	West
214		Saratoga	Cir	1984	070824221025	West
222		Saratoga	Cir	1984	070824221041	West
5		Wood Crest	Ct	1984	070918312102	West
17		Wood Crest	Ct	1983	070918312136	West

## Appendix D: Report Revisions

[illegible]