EXECUTIVE SUMMARY

This study investigated the potential water savings of advanced water treatment on typical urban supermarket cooling systems. Water use patterns in the remainder of the store were also investigated as a secondary subject. The goal of the study was to quantify the water saving potential and the economic feasibility of advanced water treatment in cooling systems, and to look for water saving opportunities in the other water uses in the stores.

This study was made possible by a grant from the California Department of Water Resources and the financial support and co-operation of the Los Angeles Department of Water and Power, the City of Santa Monica, the Upper San Gabriel Water District, the Eastern Municipal Water District and the Irvine Ranch Water District.

The sites included in this study were all typical full-service type urban supermarkets operated by companies such as Ralphs, Stater Brothers, Albertsons and Vons. For confidentiality purposes none of the precise stores are identified, but they are referred to according to their location: Arcadia, Beverly, Irvine, Santa Monica, Sun City and USC. These stores were typically 50,000 sf in size and had multiple departments. Some had full kitchens and food preparation areas and other had minimal food preparation. All had some form of meat, produce, bakery and service deli.

The baseline water use characteristics of the stores are shown in the Table ES-1. These stores, which were chosen at random, used an average of 3.5 million gallons of water per year, which was split nearly 50:50 between cooling use and other in-store uses. Daily cooling use and in-store uses equaled approximately 4,100 gpd. It was also found that the cooling use of the stores was split between evaporation and bleed such that evaporation accounted for approximately 2400 gpd and bleed used 1700 gpd. The average concentration ratio of the cooling systems during the baseline period was approximately 2.45.

Table ES-1: Summary of baseline water use in 6 study stores (kgal)

	ARC	**BEV**	**IRV**	**SC**	**SM**	**USC**	**Average**
Water Meter Data							
Annual Use	2244	5064	4044	1908	4512	3408	3530
Ave Month	187	422	337	159	376	284	294
Ave Day	6.15	13.85	11.25	5.3	12.53	9.48	9.76
Daily Use During Logging							
Total Daily Use	4.924	9.047	10.734	5.389	12.447	8.948	8.582
In-Store Use	1.313	4.596	6.867	2.357	5.033	4.601	4.128
Total Cooling Use	3.61	4.451	3.867	3.032	5.431	4.347	4.123
Bleed	0.973	1.283	1.547	1.399	3.026	1.859	1.681
Evaporation	2.638	3.168	2.23	1.633	2.404	2.489	2.427

The energy use at the stores was examined because there is a close link between energy use and cooling at these stores. It is well known that a cooling system that has scale problems will use more energy for refrigeration than one with clean condenser tubes. The baseline energy use for the stores is shown in Table ES-2. On average, these stores use over 2.3 million kWh per year, which is a significant amount of energy consumption. At $.06/kWh this comes to an annual power bill of $138,000.

Table ES-2: Baseline energy use at study sites

2001	**Sun City**	**Irvine**	**Arcadia**	**Beverly**	**USC**	**Average**
Total Annual (kWh)	1,671,120	3,295,477	1,421,174	2,919,168	2,333,280	2,328,044
Avg. Month (kWh)	139,260	274,623	118,431	243,264	194,440	194,004
Std. Dev. (kWh)	8,704	23,348	9,022	16,025	15,822	14,584

Essential to any cooling system analysis is a discussion of the basic concepts of cooling water use in relationship to the cycles of concentration of the water in the cooling systems. Two key relationships between cycles of concentration and bleed water use are presented. The first is the definition of concentration ratio as the ratio between the total feed water and the bleed water, or $CR = M/B$. This tells us that as long as the amount of bleed water is proportional to the amount of water entering the system the concentration ratio will remain constant irrespective of variations in the inflow water chemistry. The other relationship is that the water used for bleed will vary inversely with the concentration ratio, such that B = E/(CR-1), where E is the water lost to evaporation. This tells us that it is physically impossible to ever achieve a concentration ratio of 1, since to do so would require an infinite amount of water. It also shows that as the concentration ratio increases the reduction in bleed water use diminishes, which can be seen in Figure ES-1. As the cycles of concentration exceed 6, the reduction in total water use becomes negligible.

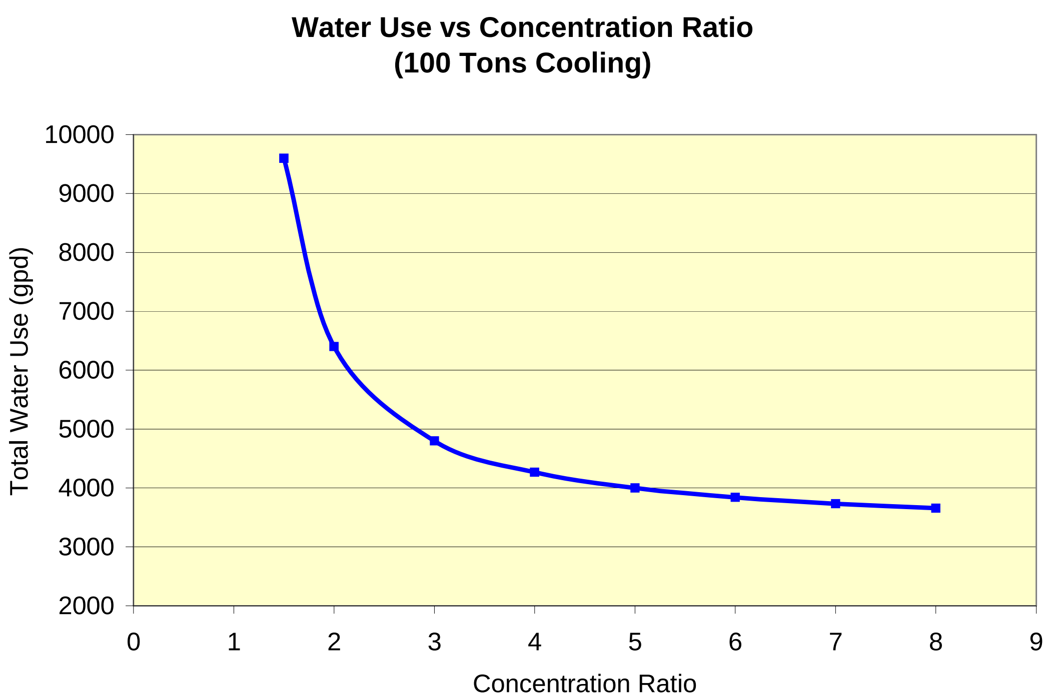

Figure ES-1: Cooling water use verses concentraion ratio.

This report also discusses the critical elements of water treatment in evaporative condensers. The major concern is the prevention of scale as the concentration of minerals in the system increases. The primary scale mineral is calcium carbonate (calcite), which is formed when calcium and carbonate alkalinity ions react. The result is an insoluble deposit of calcium carbonate on the tubes and internal surfaces of the system. Because calcium carbonate is so insoluble this reaction occurs whenever the carbonate ion is the primary form alkalinity present in the water. This is the situation when the pH in the system exceeds 8.3. Conventional water treatment normally operates at pH levels of 8.8 or higher, but it aims to retard the scale formation using chemical threshold inhibitors. This will delay scale formation, but will not prevent it. Advanced water treatment, such as alkalinity control, makes calcium carbonate formation impossible by keeping the pH below the 8.3 threshold, where the primary alkalinity ion is the bicarbonate ion, which is soluble with calcium.

Even if calcium carbonate formation is prevented there are a wide range of other scale forming minerals that can precipitate onto the pipes. These can include the very chemicals that are being added to prevent scale formation in the first place, if they are overdosed. Important scale minerals that need to be watched for include calcium sulfate (gypsum) which can form whenever the concentration of calcium and sulfate exceed critical levels. This is a serious concern in systems that are using sulfuric acid (H_2SO_4) for alkalinity control. Calcium phosphate and calcium phosphonate are also concerns since phosphates and phosphonates are frequently used for scale and corrosion inhibitors. Magnesium silicate is an especially difficult scale to remove, and is of concern where the feed waters are high in silica.

Besides scale formation, the two other water management problems in evaporative condensers are biological fouling and corrosion of the copper and steel metals they contain.

There are a wide range of chemicals used to control scale, corrosion, and biological fouling. The treatment is complex since chemicals which may be used for one problem without incident may react with others used for other reasons, and this reaction my create a scale or corrosion problem that would not be predicted by use of either chemical alone. An example of this would be the use of chlorine for biological control reacting with phosphonates to release phosphate, which then combines with calcium to form calcium phosphate scale.

The key to a successful water treatment program is in having an experienced water treatment contractor with trained chemists supervising the program and performing periodic testing and observations.

Three water treatment technologies were investigated in this study. Two of the six study sites were used for each system. The Zeta Rod, tested at Sun City and USC, uses static electricity to induce a strong similar charge on the scale particles in an attempt to keep them in suspension and from accumulating into a solid scale formation. This is a form of electrical dispersion, and parallels certain chemical processes, which seek to do the same thing with chemical agents.

The Scale Viper was tested at Arcadia and Beverly. This is a system that uses pulsing electromagnetic radiation to modify the crystal formation process and allow the hardness minerals to precipitate out of solution as a harmless aragonite powder, which can be removed from the sump during routine cleaning.

The third process was the chemical process of alkalinity control, which uses a feed of sulfuric acid to neutralize alkalinity in the circulating water and keep the pH below 8.3, the inflection point between calcium bicarbonate and calcium carbonate. By keeping the pH below 8.3 the concentration of calcium carbonate is kept low, carbonate scale formation is prevented.

The results of the test showed that each of the systems has drawbacks, but that the alkalinity control program can successfully operate at higher cycles of concentration without causing either scale or corrosion to the system.

The Zeta Rod and Scale Viper system did not prove capable of staying ahead of the scale at the concentrations found in these systems. All four of the test sites that used these systems developed aggressive scale formations within 30 to 60 days of the start of the test. These systems were discontinued, and one of the sites, Beverly, was converted to alkalinity control.

Of the three systems using alkalinity control all operated at cycles of concentration of 5.5 or more and none experienced calcium carbonate scale. Also, the corrosion rates were excellent in all three sites. By August, however, after nearly 10 months of operation, a soft scale had begun to appear on two systems using chemicals from the same supplier. These were tested and showed high levels of phosphate in the scale. Steps were being taken to eliminate these problems as of the date of this report.

The water savings achieved at the six sites exceeded the amounts predicted by the theoretical calculations. This is probably because the actual change in cycles of concentration was greater than those assumed in the calculations. The amount of water saved at each site is shown in Table ES-3. This shows that on average, the shift from conventional to advanced treatment resulted in savings of 709 kgal per year (948 ccf). The least amount of water saved was 496 kgal per year at Irvine, and the greatest savings were 1072 kgal at Santa Monica. These savings were exclusively from the changes to the cooling operations, and were measured using the water meters on the cooling systems themselves.

Table ES-3 Water savings at six study sites

Store	Savings (gpd)	Kgal/month	Kgal/year
Arcadia	2135	65	781
Beverly	1714	52	627
Irvine	1354	41	496
Santa Monica	2930	89	1072
Sun City	1641	50	601
USC	1844	56	675
Average	1936	59	709

The benefits derived from an advanced water treatment program are threefold: 1. A reduction in water use and lowered water and wastewater charges; 2. Reductions in electrical use due to less scale on the tubes and lower energy requirement for cooling; and 3. The ability to reduce the amount of acid washing required to keep the system scale free, and with it the extension of the life of the cooling tube bundle and side walls.

An economic evaluation of the system was conducted assuming each used the same alkalinity control program and achieved the savings that were observed at each site during the test. Costs of installation and incremental operations were included. Benefits from reduced water and wastewater, a 5% reduction in electrical consumption and avoidance of a major overhaul in year 15 of a 25-year life cycle were included. All costs and benefits were brought back to a present worth using a discount rate of 5%. The results of this analysis are shown in Table ES-4.

Table ES-4: Economic analysis of alkalinity control program

Store	Water Savings	Combined Rates	Baseline Energy Use	Savings Present Worth $				Cost PW	Ben/Cost Total	Ben/Cost Water
	kgal		kWh	Water/WW	*Energy*	Maint	Total			
Arcadia	781	$5.14	1,421,174	$69,876	$74,213	$24,051	$168,139	-$26,946	6.24	2.59
Beverly	627	$5.60	2,919,168	$61,118	$152,437	$24,051	$237,606	-$26,946	8.82	2.27
Irvine	496	$2.97	3,295,477	$25,642	$171,819	$24,051	$221,512	-$26,946	8.22	0.95
Santa Monica	1072	$5.67	2,500,000	$105,801	$130,848	$24,051	$260,700	-$26,946	9.67	3.93
Sun City	601	$2.06	1,671,120	$21,550	$88,156	$24,051	$133,758	-$26,946	4.96	0.80
USC	675	$5.60	2,333,280	$65,797	$122,261	$24,051	$212,108	-$26,946	7.87	2.44
Average	709	$4.51	2,356,703	$58,297	$123,289	$24,051	$205,637	-$26,946	7.63	2.16

It is noteworthy that four of the six sites showed a strong benefit to cost ratio for conversion to alkalinity control using only the savings in water and wastewater on the benefits side of the equation. The two sites that had ratios less than 1 both had unusual rate structures. In Sun City that had the lowest ratio (0.8) they do not charge for wastewater on a unit consumption basis, so there were no savings to be credited from reductions in wastewater flows. In the other, Irvine, which had a ratio of 0.95 they are using a fairly new water budget system, and the allocations they have provided to the supermarkets appear to be too generous, since the cover all of the water use at the store, under the conservation rate, even though it is known that there is ample room for conservation at this store.

All of the other sites which had more traditional rate structures showed benefit cost ratios for conversion to alkalinity control of 2.16 or more, and the maximum site, Santa Monica, had a ratio of 3.93. If allowances are made for reasonable savings on electricity and avoided maintenance then the benefit cost ratios rise dramatically. In this case the lowest B/C ratio is nearly 5 and the highest is nearly 10.

The conclusion of this study is that a well run alkalinity control program can pay for itself in one or two years, and that over the life of a new evaporative condenser the benefits from using advanced water treatment will be between 2 and 10 times the incremental costs of using the system.

Recommendations for other in-store water savings included the use of high efficiency spray nozzles, aerators, and water flow restrictors on all hand sinks and spray tables. Another recommendation would be for the elimination of garbage grinders in favor of composting produce wastes, as well as replacement of low pressure hoses with high-pressure sprayers for washing the meat department. All of the stores in this study already had ULF toilets and urinals, but in these would be the first step in stores that don't already have them. Finally, the development of an education program that encourages employees to report leaks and wastage and rewards them for conserving water is an essential step in obtaining support and co-operation of the employees.

It seems reasonable that with an aggressive campaign of cooling and in-store conservation it should be possible to save over 800 kgal per year on average per store, which is nearly 2.5 acre feet per store. These are the kinds of savings that could add some major volumes if applied to the entire southern California area. Hopefully future work will confirm this.