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**WATER CONSERVATION PROGRAM
CITY OF ARVADA, COLORADO**

**Sterling E. Schultz, P.E. PhD
Utilities Manager
City of Arvada
Colorado**

WATER ORGANIZATIONS IN A CHANGING WEST

**Natural Resources Law Center
University of Colorado
School of Law
Boulder, Colorado**

June 14-16, 1993

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**WATER ACCOUNTABILITY AND CONSERVATION
STERLING E. SCHULTZ, UTILITIES MANAGER
CITY OF ARVADA
ARVADA, COLORADO**

The City of Arvada water utility has undertaken various actions to improve the accounting for all water throughout the water system and to achieve water savings within the community it serves. The actions include an annual systemwide water audit, distribution system leak detection, improved preventive maintenance, and a comprehensive water conservation program. The cost effectiveness of many of these efforts have been well documented, while others in the water conservation program will continue to be monitored for several years to determine the permanency of the water demand reduction. Arvada has always advocated wise water use and metered all of its customers. Traditionally, it planned to supply future water needs for continued growth through the purchase and development of additional water supplies. However, since the late 1980s, the securing of large new water supplies for Arvada has become less certain and the utility turned its attention to better management of present water supplies and towards reducing customers' water consumption. Thereby Arvada expects to stretch existing water supplies. To measure the effectiveness of these efforts, it became apparent that tighter accountability of all water uses would be necessary. The utility embarked on reducing the annual volume of unaccounted-for water, i.e., system losses.

Improving Water Usage Accountability

The annual systemwide water audit determines the system losses. The overall objective is to quantify all usage as accurately as possible. Total water usage is made up of metered usage and estimated usage. For Arvada, as many water users are metered as practical including the customers that are billed bimonthly, the wholesale contract distributors, invoiced water sales at construction sites and truck fill stands, and metered utility uses including raw water purchases and water treatment uses. All potable water production delivered to the city is metered as it leaves the treatment plants. Other volumes of water are readily measured by keeping monthly records of the number of times vehicle tanks are filled for street sweepers and jet trucks for sewer cleaning. There are other uses that can be estimated fairly accurately if crew members are properly trained and a continuing emphasis on record keeping is maintained, including flushing of water mains, emergency repairs, fire department usage, hydrant maintenance and others. Arvada's system loss summary and worksheet for 1992 are shown in Tables 1 and 2. Figure 1 illustrates the water accountability for 1992 by customer classifications. After five years of concerted efforts, the utility can attribute a low overall system loss of 4 percent to the installation of accurate and precise raw water meters, metering all practical usage, a comprehensive meter maintenance and calibration program, and thorough documentation of estimated usage. It has generally been considered by the water works industry that water systems operating with a 10 percent loss are performing very well. The average unaccounted-for water for utilities in the Denver metropolitan area is 7.3 percent.

Raw water delivery is metered by four 12-inch positive turbine meters manufactured by Daniel Industries, Inc., Houston, Texas, and equipped with electronic instrumentation to measure volumetric total flow and flow rate. These precision meters, normally used to measure precious liquids, have a linearity accuracy of ± 0.25 percent. They have been in continuous service since 1986 and are virtually maintenance free and always within specified operating accuracy as required by the Denver Water Department.

The utility's comprehensive meter maintenance and calibration program services all 1½ inch and 2 inch meters in the system biannually and all 3 inch and larger meters every year. In 1992, this effort accomplished the servicing of 237 - 1½ inch, 86 - 2 inch, 25 - 3 inch, 59 - 4 inch, 10 - 6 inch and 2 - 8 inch water meters. All 194 park irrigation turbine meters, ranging in size from 5/8 to 3 inch, are tested annually for accuracy. The turbine meters are still holding their accuracy after 4 to 6 years in service. The annual benefit-to-cost effectiveness of the meter maintenance program is about 1.5:1 based on the revenue recovery to the cost of the large meter maintenance program. The water sales revenue loss from under registration of meters is an important concern to the utility; however, of equal concern to the utility is the protection of the customers against meter inaccuracy that could result in overcharges.

Leak Reduction Program

Distribution system losses from leaks have been curtailed by systematic surveying of about one-third of the system annually. Although originally purchased for finding non-evident water system leaks, the sophisticated leak detection and correlation equipment manufactured by Fluid Conservation Systems, Houston, Texas has pinpointed evident and non-evident leaks to within two feet of the actual leak on all types of distribution system pipe except PVC. On 36 inch and larger diameter transmission pipeline an access point to the pipe within 1,000 lineal feet of the leak is necessary for accurate pinpointing of the leak. The utility operates the leak detection program from a van with one city employee for about \$30,000 per year. The benefit-to-cost ratio for this program is about 2:1. The ability to confirm no leaks and thus avoid costly excavation looking for a leak is a very beneficial capability of the equipment which also avoids potential liability claims for seepage. Table 3 summarizes Arvada's leak detection program annually since 1988.

Water Use Profiles for Customers

Accountability of water after delivery to customers is important too. Leaks waste water and high water bills only upset customers if they feel they are paying for something they didn't get. Thus, the water utility has implemented a water-use profiling service for customers. Portable flow recording instruments that are compatible with all magnetic drive water meters in the Arvada system are used to monitor water flow rates at interval settings ranging from 1 to 240 seconds as well as recording the total volume of water passing through the meters to which they are attached. The portable flow recorders are manufactured by F.S. Brainard and Company, Burlington, New Jersey. Arvada

has two each of the two available models: (1) the Meter Master Model 100 which is small enough to fit inside a standard residential water meter pit, and (2) the Meter Master System III for use with compound and fire flow meters. Both models utilize a magnetic sensor to count pulses from a meter's magnetic drive. A gear-driven meter converter is also available to permit use with gear driven meters. The pulses are logged into the instrument's memory to be later downloaded into a standard IBM-compatible personal computer and converted into reports and graphs via software. Set up of the Meter Masters in the field is simple, requiring only velcro straps to securely position the magnetic sensor where the signal generated by the internal magnets is strongest. Operation of the Meter Master 100 is initiated and accurately verified without the need for a personal computer in the field; the Meter Master System III requires a lap top computer in the field for start-up, copying and printing. Both Meter Master models are durably built and have performed very satisfactorily for Arvada.

As previously mentioned, the Meter Master portable flow recorders are used extensively by the utility for satisfying customers' concerns about high volume water usage (high water bills). The recorders can be used over an extended period up to two weeks if need be, but usually within 24 to 48 hours the customer can be shown from the recorded data in tabular or graphic format that there is a continuous or intermittent water leak -- or the water usage is high and there is no leak. The recorders have been used repeatedly to help customers find leaky toilets and irrigation systems; multifamily apartment managers have been able to isolate leaks or renters who are deliberately wasting water. Table 4 is an example of a standard report showing a continuous flow through the meter varying from 0.13 to 0.72 gpm. Customer satisfaction has been very high and all are thankful for the utility providing such a service to them.

The water utility also uses the flow recording instruments to determine if an installed meter is the correct size and type for its application. As Figure 2 and Table 5 show, the meter is operating within its recommended sustained operating flow rate. These recorders have proven to be cost effective for the utility and their use for customers is perceived as being customer oriented.

Water Conservation

Water utilities have traditionally supplied their future water needs through the purchase and development of additional water supplies. However, being located in a semi-arid environment makes future availability of securing large new water supplies less certain. Many municipalities, including Arvada, are turning more of their attention and efforts towards the customers' water demand, i.e., water consumption. Arvada expects to stretch existing water supplies through water conservation.

Opportunities to Reduce Water Demand

Arvada's demand for water, apart from seasonal fluctuations, is primarily driven by the residential sector with over 92 percent of the billing accounts and

75 percent of the total water consumption by residential households. Clearly, Arvada initially focused its water conservation efforts on the residential sector.

The average single family household water usage over the last three years in Arvada was 141,000 gallons per year. The monthly profile for this average annual usage is shown in Figure 3. The average household consisted of three persons and a lot size of 9,500 square feet. Looking into the purposes for water uses in the average single family household as shown in Figure 4, one finds that 49 percent of the usage is for landscape irrigation. The next highest percentage of use is for bathing at 19 percent, followed closely by toilet flushing at 16 percent. Again, it was clear that Arvada should focus its conservation efforts on education and incentives to reduce water consumption by toilets, showers, and landscape watering. The potential water savings from using conserving plumbing fixtures or retrofit devices is shown in Figure 5. By reducing the turf area and incorporating other water conserving plant materials into the landscape the outdoor watering demand can be reduced by up to 50 percent or more as widely reported in water conservation writings. With the help of a citizens advisory committee and strong support from the city's public officials, a conservation master plan was prepared and implemented in 1988. A work plan is annually prepared and funding requested as part of the routine budget process. Prior to implementing any conservation program measures, their projected water savings associated with their target market penetration were determined using published work of others. All measures implemented were calculated to be cost effective based on the cost for the volume of water projected to be saved compared to the cost of new water rights purchased at current prices. The 1988 to 1992 average price paid for water rights by the city was \$5,500 per acre-foot.

Conservation Effectiveness

The water utility has an intensive monitoring program to quantify the water savings attributable to various conservation measures and will continue such efforts to establish the permanency of the water demand reduction. Customers' water billing records, special metering, and followup surveying of participants in various program measures are being used to document the monitoring efforts.

To evaluate the cost effectiveness of conservation, the volume of water saved and the cost to achieve this savings is compared to the cost of buying an equivalent amount of new water in the open market.

Conservation Program

Arvada's water conservation program assists and encourages water customers to reduce water usage without sacrificing their quality of life; the program relies primarily on voluntary participation. The water conservation measures include:

Ultra Low Volume Toilet Rebates. An \$80 rebate is paid to anyone who replaces a non-conserving toilet with an ultra-low-volume toilet (ULV) which uses 1.6 gallons of water or less per flush. To date, a total of 1,770 rebates

have been paid and the average reduction in indoor water usage for these households is 15.1 percent. The cost to the city for the water saved from the \$80 ULV rebate program was \$3,270 per acre-foot. Conversely, the average price paid to buy new water supplies is \$5,500 per acre-foot. Thus, through the rebate program the city paid \$2,300 per acre-foot less to stretch its existing supplies rather than purchase new water and additional storage.

Free Residential Water Audits. During the audits, homeowners are encouraged to have water saving retrofit plumbing devices installed including "Future Flush" devices for the toilets and "Niagara" showerheads, shown how to read their water bills, and instructed how to improve landscape watering practices. To date, 3,339 audits have been completed. The percent reduction in indoor water usage has been 10.7 percent by comparing indoor water usage history for the past 3 years to indoor usage following the audit. The cost to the city for the water saved though the audit program was \$2,295 per acre-foot less than buying new water.

Conservation Incentive Water Rates. A two-tiered water rate structure rewards both indoor and outdoor conservation. The volume usage which trips the higher rate is 30,000 gallons bimonthly. The city determined that if a typical home on a 1/4 acre lot replaced 43 percent of their bluegrass lawn with alternative water conserving landscaping, they could reduce their bimonthly watering requirements to less than 30,000 gallons.

Although it is impossible to assign any quantitative impact of water conservation rates on usage, Arvada believes rates are one important element in an overall strategy to achieve long-term reliability in water demand reduction through conservation. After all, pocketbook considerations can be an important lever in changing peoples' water usage habits. A very important part of this measure is customer education of how to conserve and customer awareness of how the water rate structure works. If they know, they will likely monitor their usage more carefully.

Conservation Ordinances. Ultra low volume toilets, low flow showerheads and faucets are required to be installed in all new construction or when any remodeling includes changes to the existing plumbing system.

Water Conserving Landscape Rebates. Arvada implemented a bold new program in 1993 to achieve four major objectives concerning landscaping: (1) reduce the volume of outdoor watering by 50% (landscape watering accounts for about 50% of the total annual residential water usage), (2) improve the water retention characteristic of poor local soils, (3) encourage home builders to incorporate soil improvements and water conserving landscapes at the time of new construction, and (4) change the homeowners' (prospective and existing) mindset about water conserving landscapes, sometimes called "Xeriscapes."

To accomplish these objectives, Arvada will rebate up to \$750 per lot to any property owner, contractor, or developer who prepares the soil and plants a water conserving landscape. A water conserving landscape in Arvada is one

that has a maximum annual watering requirement of eight gallons per square foot of landscaped area. The landscape plan must be city approved and a minimum area of 3,500 square feet must be landscaped to be eligible for the maximum \$750 reimbursement.

Public Education and Conservation Awareness. News articles, educational seminars, brochures, and water conservation inserts in the utility bills are generously used for informing customers about how water consumption can be reduced without sacrificing their quality of life. The city is also in the process of upgrading many of its parks and other public irrigation systems to increase watering efficiency of these areas and serve as a good example of its commitment to water conservation. Through the bi-annual Citizen Attitude Survey, water customers have continued to express strong support for the city's water conservation efforts and the financial resources used to carry out the program.

Conclusion

If utilities are to quantify the permanency of water demand reductions achieved through conservation practices, then accountability of water in the total system must be assured. The City of Arvada has implemented proposals and procedures long advocated by others in the water works profession to achieve improved water supply and demand management. Arvada has undertaken the comprehensive water accountability and conservation programs to extend its existing water supplies in a cost effective manner and to minimize the need for new water supply projects in the future. Perhaps Arvada's experience and lessons learned can be of assistance to other utilities developing and implementing water accountability and conservation programs.

TABLE 1
CITY OF ARVADA, COLORADO
WATER UTILITY
System Loss Summary
For Arvada Service Area

January 1, 1992 through December 31, 1992

1.	Raw water delivered for treatment from Denver supplies (gallons)	<u>4,136,517,000</u>
2.	Raw water delivered for treatment from Arvada supplies (gallons)	<u>1,204,110,000</u>
3.	Water produced from wells (gallons)	<u>0</u>
4.	Emergency water delivered to Arvada Service Area* (gallons)	<u>0</u>
5.	Total water required, Items 1+2+3+4 (gallons)	<u>5,340,627,000</u>
6.	Total water metered to customers (gallons)	<u>5,124,959,026</u>
7.	System loss, Items 5 - Item 6 (gallons)	<u>215,667,974</u>
8.	System loss, Item 7 ÷ Item 5 X 100 (percent)	<u>4.04%</u>

Sterling E. Schultz
Utilities Manager

* Total water delivered through interconnection(s) between the Arvada Service Area and Arvada Supplemental Service Area during emergency.

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TABLE 2
CITY OF ARVADA, COLORADO
WATER UTILITY
System Loss Summary
January 1, 1992 through December 31, 1992

<u>TOTAL WATER ACCOUNTED FOR:</u>	<u>ALL FIGURES IN GALLONS</u>
<u>Measured Usage</u>	
City Customer Billings	4,844,815,000
Distributor Contracts:	
Wheat Ridge, Leyden, Ridge Home, Ralston Valley	<u>185,523,000</u>
Sub Total	5,030,338,000
<u>Measured Usage</u>	
Storage Tanks27,265,000
Street Sweepers354,062
New Line Storage206,071
Invoiced Water Sales	2,437,500
Sewer Cleaning - Jet	<u>578,000</u>
Sub Total	30,840,633
<u>Estimated Usage</u>	
Flushing Mains	9,674,000
Emergency Repairs	10,402,911
Fire Department Usage	2,800,407
Hydrant Maintenance	1,411,000
Contractor Aid	4,449,075
Customer Service946,000
Miscellaneous114,000
Backwash Pond Cleaning	<u>.33,983,000</u>
Sub Total	63,780,393
TOTAL WATER ACCOUNTED FOR	5,124,959,026

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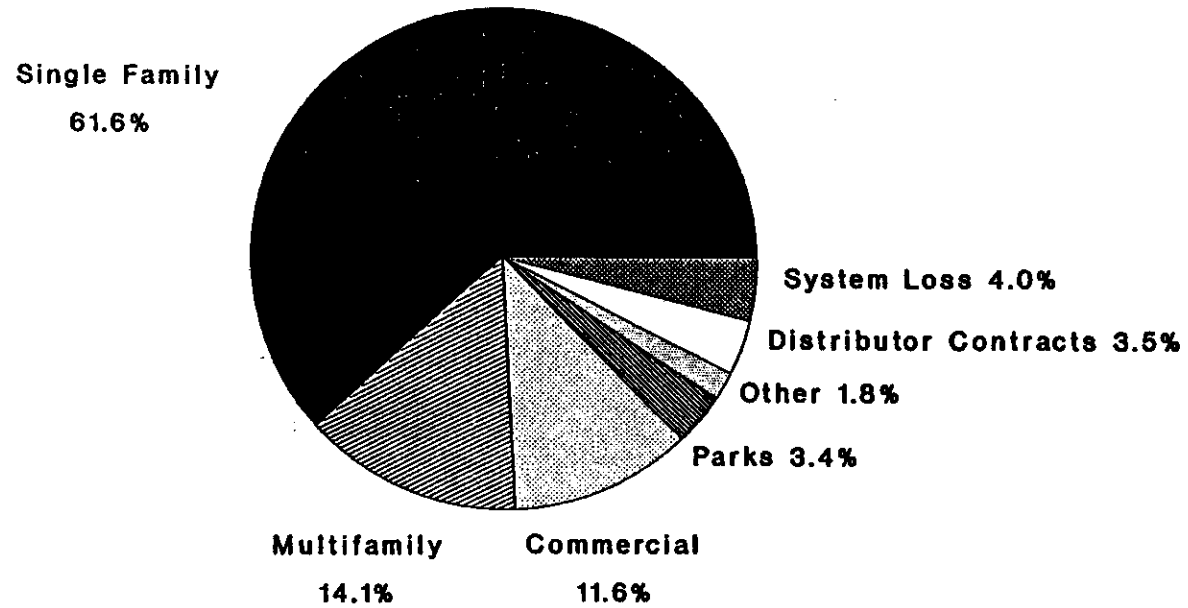
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FIGURE 1

City of Arvada, Colorado

Water Accountability for 1992



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TABLE 3
LEAK DETECTION PROGRAM SUMMARY
City of Arvada

Year	Distribution System Surveyed (miles)	Non-Evident Leaks Found (each)	Leaking Fire Hydrants (each)	Evident Leak Sites Surveyed (each)	Evident Leaks Pinpointed (each)	No Leak Verified (each)	Leaks Not Pinpointed (each)	Customer Service Leak Detection (each)	Cost Savings (\$)
1988	205	9	9	57	28	13	16	39	69,500
1989	106	0	3	86	46	25	15	85	57,550
1990	213	0	25	50	24	13	13	60	51,250
1991	94	7	9	78	44	25	9	84	192,650
1992	65	1	6	109	52	37	20	73	70,350
Totals	683	17	52	380	194	113	73	341	441,300

- There are 395 miles of water transmission and distribution pipelines in the system.
- Cost savings include the amount of annual revenue lost because of the leak and the excavation costs avoided by pinpointing the leak or confirming that no leak existed. Cost figures are in dollar value for each respective year.
- Capital equipment costs in 1988 were \$60,370 and included the leak detection equipment at \$45,000, supporting equipment at \$4,000, plus \$11,370 for a van.
- The annual operating costs are \$30,000/year and include the salary for one detection equipment operator.
- The excavation savings due to pinpointing is between \$500 - \$800 per site depending on the site.
- The total water loss due to leaks totaled 123 million gallons for the 5-year period.
- Benefit to cost ratio for the overall program is conservatively 2.1.

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TABLE 4

METER-MASTER Program Version 1.0
 Copyright 1992 - F.S. Brainerd & Co.
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Customer: RUBY APTS.
 Location: 7655 W 54TH AVE
 Acct No: 1624001

Notes: CUSTOMER REQUEST

Primary File Name: 1624001.HDR
 Report File Name: 1624001.RPT

Data Start Time: 03/03/93 14:10:13
 Data End Time: 03/04/93 14:02:13

Meter Make: Sacoer
 Meter Model: RCCL
 Meter Size: Model 70
 Unit of Measure: Gallons
 Report Interval: 240
 Max-Min Interval: 240
 Total Volume: 1032.25

Report Start Time: 03/03/93 14:10:13
 Report End Time: 03/04/93 14:02:13
 Total Hours: 23.87

Time	Vol/Int	Avg	Max	Min
03/03/93 14:14:13	1.63	0.41	0.41	0.41
03/03/93 14:18:13	2.27	0.57	0.57	0.57
03/04/93 01:22:13	0.51	0.13	0.13	0.13
03/04/93 01:26:13	0.56	0.14	0.14	0.14
03/04/93 01:30:13	0.56	0.14	0.14	0.14
03/04/93 01:34:13	0.51	0.13	0.13	0.13
03/04/93 01:38:13	0.60	0.13	0.13	0.13
03/04/93 01:42:13	0.56	0.14	0.14	0.14
03/04/93 01:46:13	2.87	0.72	0.72	0.72
03/04/93 01:50:13	0.51	0.13	0.13	0.13
03/04/93 01:54:13	0.56	0.14	0.14	0.14
03/04/93 01:58:13	0.60	0.13	0.13	0.13
03/04/93 02:02:13	0.54	0.16	0.16	0.16
03/04/93 02:06:13	2.22	0.71	0.71	0.71
03/04/93 02:10:13	0.63	0.17	0.17	0.17
03/04/93 02:14:13	0.81	0.20	0.20	0.20
03/04/93 02:18:13	0.68	0.17	0.17	0.17
03/04/93 02:22:13	0.60	0.15	0.15	0.15
03/04/93 02:26:13	0.56	0.14	0.14	0.14
03/04/93 02:30:13	0.51	0.13	0.13	0.13
03/04/93 02:34:13	0.51	0.13	0.13	0.13
03/04/93 02:38:13	0.28	0.14	0.14	0.14
03/04/93 02:42:13	0.51	0.13	0.13	0.13
03/04/93 02:46:13	0.51	0.13	0.13	0.13
03/04/93 02:50:13	0.56	0.14	0.14	0.14
03/04/93 02:54:13	0.51	0.13	0.13	0.13
03/04/93 02:58:13	0.51	0.13	0.13	0.13
03/04/93 03:02:13	0.51	0.13	0.13	0.13
03/04/93 03:06:13	0.51	0.13	0.13	0.13
03/04/93 03:10:13	0.51	0.13	0.13	0.13
03/04/93 03:14:13	0.51	0.13	0.13	0.13
03/04/93 03:18:13	0.51	0.13	0.13	0.13
03/04/93 03:22:13	2.70	0.67	0.67	0.67
03/04/93 03:26:13	0.56	0.14	0.14	0.14
03/04/93 13:58:13	0.31	0.20	0.20	0.20
03/04/93 14:02:13	0.31	0.20	0.20	0.20

Customer Concerns: High water usage and bills.

Findings: There was a continuous flow of water through the meter varying from 0.13 to 0.72 gpm during each of the four minute recording intervals. This continuous flow rate most likely represents leaking toilets in the 12-unit apartment building.

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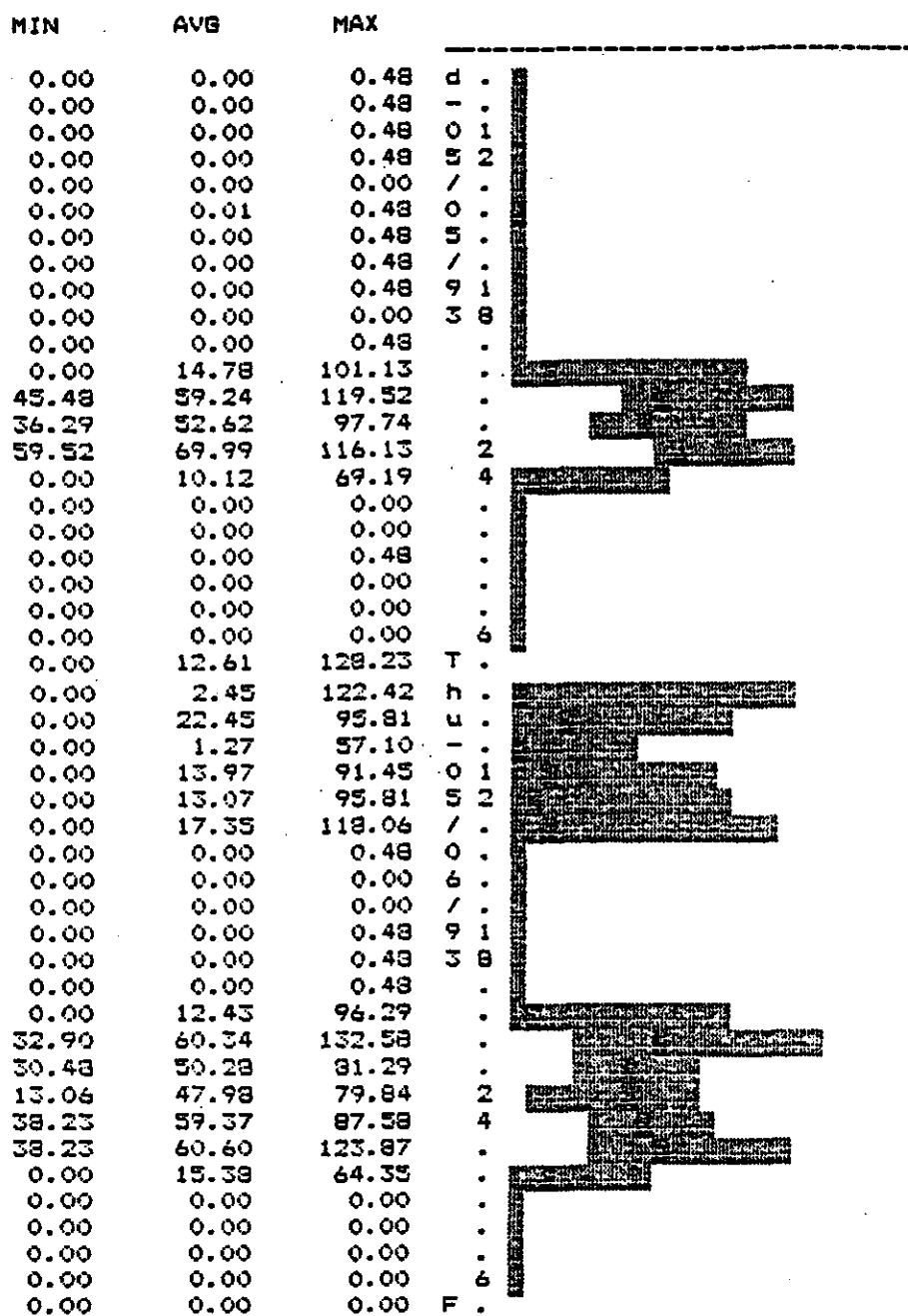
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FIGURE 2

60 MINUTE GRAPH FOR MEYERS POOL IRRIGATION



Utility Concerns: Proper meter size and type for irrigation system, check for leaks in irrigation system, and validate watering only at night.

Findings: There are no water leaks and the meter is the proper size and type. Watering did occur during the day.

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TABLE 5

METER-MASTER Program Version 1.0
 Copyright 1992 - F.S. Brainard & Co.
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Customer: MEYERS POOL IRRIGATION
 Location: 7900-A CARR ST
 Acct No: 2792801

Notes: LEAK DET. HIGH/LOW CONS PATTERNS

Primary File Name: 2792801A.HDR
 Report File Name: 2792801B.RPT

Data Start Time: 05/06/93 08:14:07
 Data End Time: 05/07/93 07:56:12

Meter Make: Sensus		Report Start Time: 05/06/93 08:14:07
Meter Model: Turbo		Report End Time: 05/07/93 07:56:12
Meter Size: W-120		
Unit of Measure: Gallons		
Report Interval: 60		
Max-Min Interval: 10		
Total Volume: 22616.78	Total Hours: 23.70	

Time	Vol/Int	Avg	Max	Min
05/06/93 08:15:07	58.55	58.55	118.55	0.00
05/06/93 08:16:07	0.00	0.00	0.00	0.00
05/06/93 08:17:07	0.00	0.00	0.00	0.00
05/06/93 08:18:07	0.00	0.00	0.00	0.00
05/06/93 21:00:07	0.00	0.00	0.00	0.00
05/06/93 21:01:07	0.00	0.00	0.00	0.00
05/06/93 21:02:07	0.00	0.00	0.00	0.00
05/06/93 21:03:07	0.00	0.00	0.00	0.00
05/06/93 21:04:07	66.21	66.21	75.48	55.16
05/06/93 21:05:07	66.61	66.61	66.77	66.29
05/06/93 21:06:07	66.21	66.21	66.77	65.81
05/06/93 21:07:07	66.29	66.29	67.26	65.81
05/06/93 21:08:07	66.37	66.37	66.77	65.81
05/06/93 21:27:07	67.90	67.90	68.23	67.74
05/06/93 21:28:07	68.06	68.06	68.23	67.74
05/06/93 21:29:07	67.74	67.74	68.23	67.26
05/06/93 21:30:07	67.74	67.74	68.23	67.26
05/06/93 21:31:07	67.98	67.98	68.71	67.26
05/06/93 21:32:07	68.06	68.06	68.71	67.26
05/06/93 21:33:07	67.90	67.90	68.23	67.26
05/06/93 21:34:07	90.89	90.89	132.58	58.06
05/06/93 21:35:07	57.58	57.58	58.06	57.10
05/06/93 21:36:07	57.26	57.26	57.58	57.10
05/06/93 21:37:07	57.34	57.34	57.58	57.10
05/06/93 21:38:07	57.10	57.10	57.58	56.61

Findings: Apparent flow rates exceeding the operating flow range in Figure 2 are confirmed in this table to only occur for one minute during irrigation zone changes.

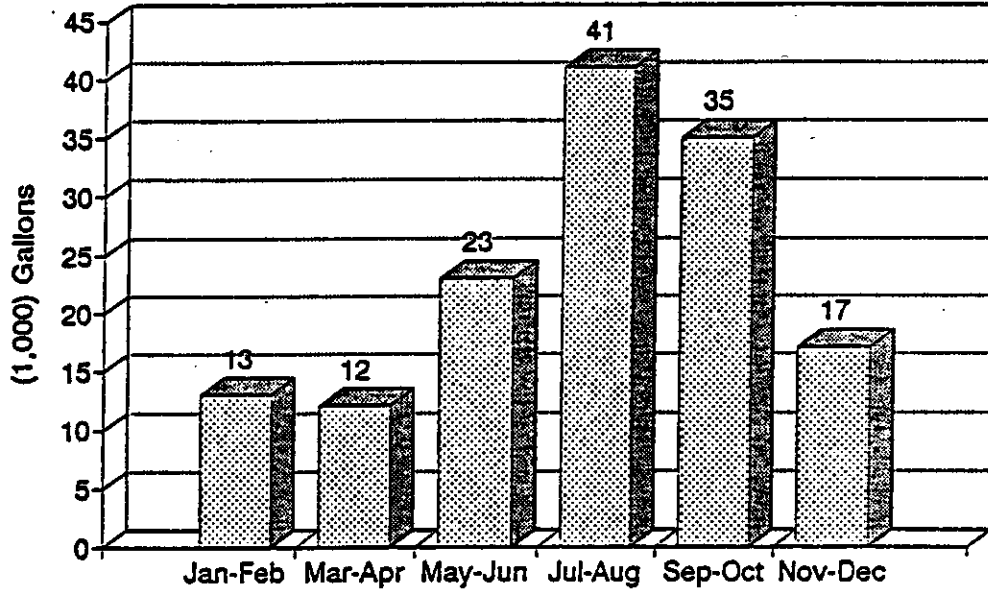
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FIGURE 3

Average Household Water Usage Profile



Note: Based on the 1988 through 1992 water use records for 1,863 households with an average of 3 persons per household and a lot size of 9,500 square feet.

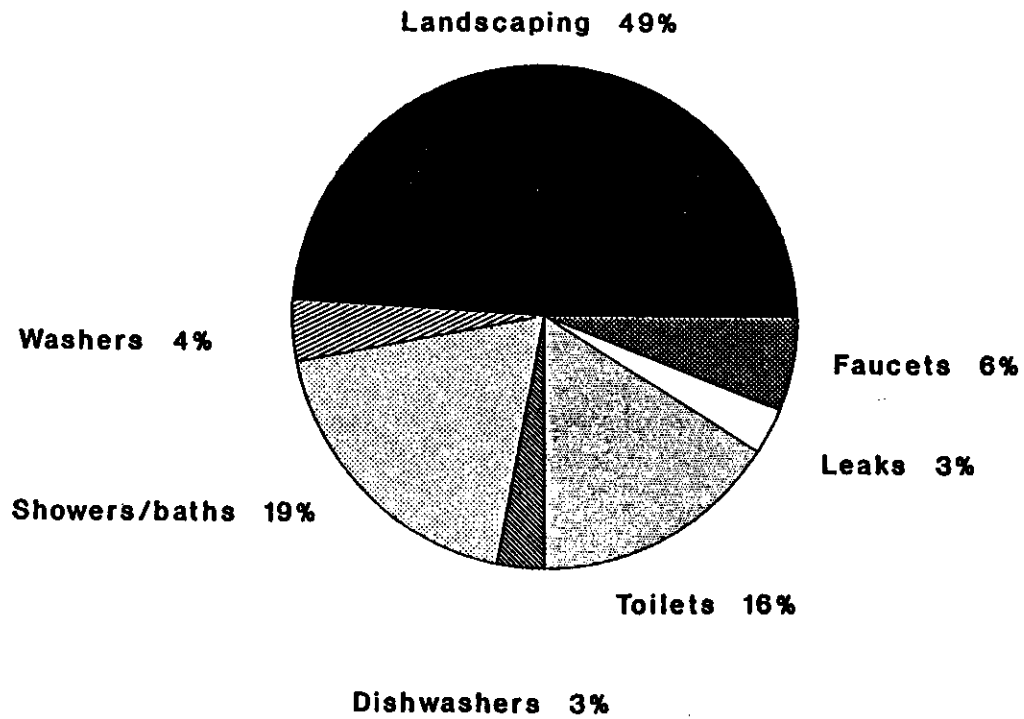
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FIGURE 4

Single-Family Residential Annual Water Usage



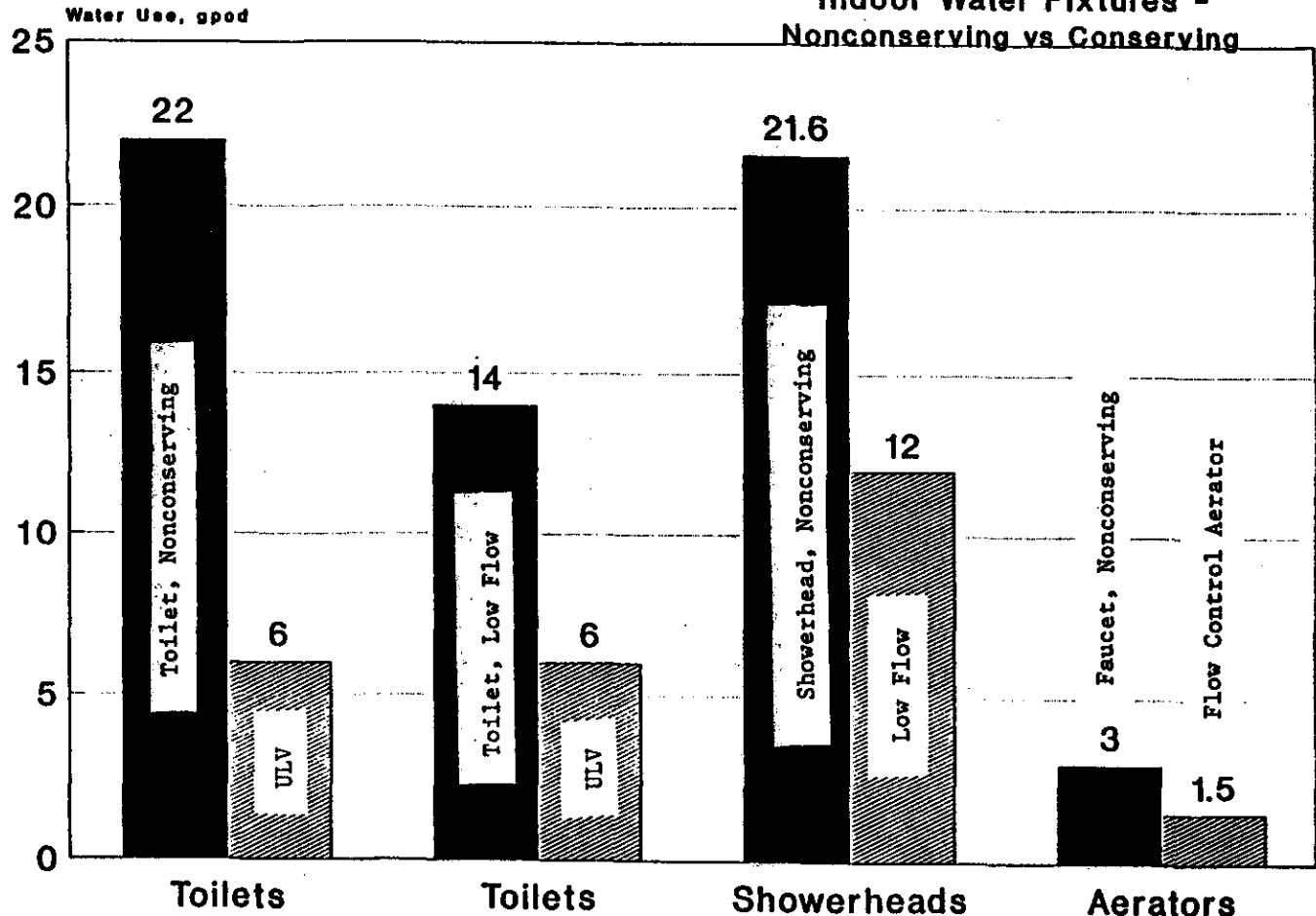
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FIGURE 5

**Indoor Water Fixtures -
Nonconserving vs Conserving**



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