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Research
Foundation

Commercial and Institutional End Uses of Water

Subject Area:
Water Resources

Commercial and Institutional End Uses of Water

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Commercial and Institutional End Uses of Water

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FOREWORD

The AWWA Research Foundation is a nonprofit corporation that is dedicated to the implementation of a research effort to help utilities respond to regulatory requirements and traditional high-priority concerns of the industry. The research agenda is developed through a process of consultation with subscribers and drinking water professionals. Under the umbrella of a Strategic Research Plan, the Research Advisory Council prioritizes the suggested projects based upon current and future needs, applicability, and past work: the recommendations are forwarded to the Board of Trustees for final selection. The foundation also sponsors research projects through the unsolicited proposal process; the Collaborative Research, Research Applications, and Tailored Collaboration programs; and various joint research efforts with organizations such as the U.S. Environmental Protection Agency, the U.S. Bureau of Reclamation, and the Association of California Water Agencies.

This publication is a result of one of these sponsored studies, and it is hoped that its findings will be applied in communities throughout the world. The following report serves not only as a means of communicating the results of the water industry's centralized research program, but also as a tool to enlist the further support of the nonmember utilities and individuals.

Projects are managed closely from their inception to the final report by the foundation's staff and large cadre of volunteers who willingly contribute their time and expertise. The foundation serves a planning and management function and awards contracts to other institutions such as water utilities, universities, and engineering firms. The funding for this research effort comes primarily from the Subscription Program, through which water utilities subscribe to the research program and make an annual payment proportionate to the volume of water they deliver and consultants and manufacturers subscribe based on their annual billings. The program offers a cost effective and fair method for funding research in the public interest.

A broad spectrum of water supply issues is addressed by the foundation's research agenda: resources, treatment and operations, distribution and storage, water quality and analysis, toxicology, economics, and management. The ultimate purpose of the coordinated effort is to assist water suppliers to provide the highest possible quality of water economically and reliably.

The "end uses" of water in the commercial and institutional service sector is a fundamental planning issue. Water conservation and resource planners need an accurate picture of how private businesses and public institutions consume water. Engineers rely upon end use information to identify design capacity and other engineering parameters. The limited availability of "high quality" water resources requires that we understand more precisely how water is used. Most existing end use information is very limited in scope. Unfortunately, engineers and planers are left to estimate commercial and institutional facility end uses in the absence of sound predictive models. This project provides a more comprehensive and accurate picture of end uses within the commercial and institutional setting.

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- Metropolitan Water District of Southern California

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EXECUTIVE SUMMARY

The purpose of the Commercial and Institutional End Uses of Water study is to:

- Summarize and interpret the existing knowledge base on commercial and institutional (CI) uses of utility-supplied potable water in urban areas,
- Present the results of field studies in a sample of 25 establishments in five urban areas,
- Provide econometric end use models for various categories of CI customers, and
- Develop a set of efficiency benchmarks for five important CI categories – restaurants, hotels and motels, supermarkets, office buildings, and schools.

The water use of CI customers involves approximately one fourth of the total quantity of water demanded for an urban area (USGS 1995). Despite the substantive proportion of total urban water use for CI customers, comparatively little attention has been focused on the water usage of this sector.

The CI sector consists of a large number of dissimilar customers with regard to the purposes of water use. The lack of benchmark measurements of the quantities of water used for cooling, cleaning, sanitary, and landscape uses within subgroups of similar establishments is an obstacle to designing CI water efficiency programs and to developing reliable estimates of CI water use and efficiency savings.

CHARACTERIZATION OF THE CI SECTOR

Variability Of CI Water Use

Heterogeneous customers with highly variable use characterize the CI sector. The variability of CI use can be examined by expressing water use in individual establishments or categories of users in terms of water use per unit, which removes the effect of establishment size, however size or scale might be measured. In cases where sector-wide use is compared between cities, the effect of the distribution of establishment sizes is also important. The total number of customers within a CI category, the number of employees, and total output (or some other appropriate volume of commercial activity) can be used to derive and compare rates of water use per unit and examine potential sources of variability. The unit rates of use are helpful in examining the relative efficiency of use among individual establishments, categories, or the CI sector as a whole in different cities.

CI Classifications and Data

The systems of classifying CI customers by water utilities are generally inadequate for comparing water use for individual categories between cities. At this point in time, only a few categories are adequately defined and comparable. These include such categories as hotels/motels, schools, restaurants, laundromats, car washes, and other easily recognizable types of businesses. Other categorizations are difficult to generalize due to lack of data. Also, a significant percentage of CI water customers do not fall into these categories and remain within the generic category of "other CI users."

IDENTIFICATION OF CONSERVATION POTENTIAL

Billing records can be used for identifying the potential for water conservation among CI customers for a given water utility based on such characteristics of water use as:

- Degree of homogeneity of water use types (or composition of end uses) within a given CI category
- Inter- and intra-class variability of per account water use
- Total water use by category relative to the CI sector use
- Number of customers within category
- Presence of seasonal water use

Categories of CI users with high cross-sectional variability of usage rates and/or variability of usage rates throughout the year are likely candidates for conservation programs. Another important consideration is the number of customers within the category that have to be approached during program implementation. Categories with fewer users that account for a significant percentage of total water use represent more focused conservation targets than categories with a large number of customers. Single large users such as an oil refinery or state university are significantly harder to move to implementation compared to a hotel chain for example.

Conservation Findings

Findings and implications regarding the design and implementation of CI conservation programs are based on the information on opportunities for water conservation described in this report:

- Some large-water-using categories have been ignored for water audits. Water audit programs need to include warehouses, correctional facilities, military bases, utility systems, and passenger terminals.
- Potential savings are in the 15 to 50 percent range, with 15 to 35 percent being typical. In addition, experienced payback periods typically range between one and four years
- Many CI water users do not need to use potable water in all applications. Each customer and water use should be examined to determine if water of less-than-drinking-quality can be used or recycled on-site, or if reclaimed effluent could feasibly be used.
- Discussion of the successes and failures of other programs can provide insight. Cooperation between water and wastewater providers, and energy utilities is essential in order to improve and optimize demand management programs.
- Category-wide benchmarks of CI water use cannot be developed on the basis of average daily or annual water use per active account (or customer) within a CI category due to the differences in size of establishments that comprise the category.

In general, water conservation programs that have been implemented are rarely well documented and evaluated. Many available documents lack direct information for generalizing water savings. There is a need for more information on program costs, implementation conditions, and measurement of savings.

SELECTION OF PRINCIPAL USE CATEGORIES

As part of this study, an analysis of CI categories and water use was performed on billing data from five participating water providers:

1. Los Angeles Department of Water and Power, California
2. Irvine Ranch Water District, California
3. City of San Diego Water Utilities Department, California
4. City of Santa Monica, California
5. City of Phoenix Water Services, Arizona

Table ES.1 presents an initial selection of eleven CI categories, which account for more than one half of CI use in the five sites. A complete set of billing records for a period of one year was analyzed including:

- Analysis of CI categories and use in each city independently
- Comparison of CI categories and use across the five sites
- Development of data that can be used to rank the categories according to conservation potential

To aid in selecting five CI categories for further investigation, these eleven CI categories were ranked according to *scaled average daily use* per customer. For a given CI category, this construct is derived as average daily use per customer (in gallons per day) multiplied by the fraction of total annual CI use accounted for by all customers in the given CI category. The scaled average daily use per account balances the rate of water used by customers in a category with the relative prominence of that category within the total use of the CI sector.

Of the eleven categories, the irrigation, car wash, and laundry categories are comprised of very specific types of end uses directed at providing specific products or water services. Although the individual customers in these categories display considerable variance in water use, it was decided that a study of conservation opportunities for these categories should be narrowly focused and perhaps better served by independent studies.

Table ES.1 Characteristics of significant CI categories in five participating agencies

Customer category description	Average annual daily use (gpdc)*	Coefficient of variation in daily use (gpdc)†	Percent of total CI use (%)	Percent of CI customers (%)‡	Percent seasonal use (%)§	Scaled average daily use (gpdc)**
Urban irrigation	2,596	8.73	28.48%	30.22%	86.90%	739.0
Schools and colleges	2,117	12.13	8.84%	4.79%	57.99%	187.0
Hotels and motels	7,113	5.41	5.82%	1.92%	23.07%	414.0
Laundries/laundromats	3,290	8.85	3.95%	1.38%	13.35%	130.0
Office buildings	1,204	6.29	10.19%	11.67%	29.04%	123.0
Hospital/medical office	1,236	78.50	3.90%	4.19%	23.16%	48.0
Restaurants	906	7.69	8.83%	11.18%	16.13%	80.0
Food stores	729	16.29	2.86%	5.20%	19.37%	21.0
Auto shops	687	7.96	1.97%	6.74%	27.16%	14.0
Membership organization	629	6.42	1.95%	5.60%	46.18%	12.0
Car washes	3,031	3.12	0.82%	0.36%	14.22%	25.0

* gpdc: gallons per day per customer
† Percent of CI customers pertains to CI customers in sites that have respective category only.
‡ Coefficient of variation in daily use: The ratio of standard deviation of daily use to average of daily use.
§ Percent seasonal use = [(total annual use - 12 x minimum month use] / total annual use
** Scaled average daily use = average annual daily use in category x percent of total CI use attributed to the category.

The auto shops and membership organization categories share similar qualities in that they are comprised mainly of specific purposes (i.e., washing and sanitary uses, respectively). Further, it was determined that the scope and intensity of water services in hospital and other health-related settings blurred the distinction between CI and "light industrial" customers. Therefore, the following five categories were selected for detailed analysis:

- Schools
- Hotel/motels

- Office buildings
- Restaurants
- Food stores

These categories represent CI customer types that are common to most cities, and which present a diversity of end uses and therefore a good basis for examining conservation.

EFFICIENCY BENCHMARKING, RESULTS FROM FIELD STUDIES, AUDIT DATA ANALYSIS, AND END USE MODELING

The statistical analysis of establishment level data for the five selected categories of CI urban water users permitted estimation of models for predicting total water use in establishments as a function of size, magnitude of operation, specific type of establishment within a broad category, and presence of specific end uses. Data for a total of 433 establishments among the five CI categories were used to develop the statistical models. These data were derived from available water use audit databases.

These audit databases and data collected from field studies of 25 CI establishments (5 from each selected category) were analyzed to determine the benchmarks of average and efficient rates of water use for each category of establishments. The derived values were compared to predictions derived from the statistical models. The comparison of results from all three sources (i.e., audit data, field study data, and modeled audit data) allowed the project team to derive expected average rates of water use for various purposes as well as approximate values of efficient use.

The efficiency benchmark was selected as the 25th percentile value for each efficiency measure. This value does not constitute an absolute measure of efficiency; instead, it represents an achievable low rate of use as evidenced by one-fourth of the sample establishments showing usage rates at or below the selected value. The efficiency benchmarks developed in this study are only approximations of efficient water usage based on the distribution of unit rates of water use in the samples of establishments in five CI categories. The results of these comparisons are presented in the following sections.

These efficiency benchmarks can be used by utilities, businesses, property managers, and others to assess the relative level of existing efficiency in establishments within the five categories. Establishments on the higher end of water use for an efficiency measure are probably the best candidates for CI conservation programs. More limited savings may be available from establishments that already use water efficiently.

Restaurants

Table ES.2 shows the comparison data for restaurants. The data suggests that an efficient restaurant would use approximately 130 to 331 gallons of water per square foot of building area in a year. Also, an efficient restaurant would use around 6 to 9 gallons of water per meal served. Furthermore, total water use for an efficient restaurant would fall within a range of use of 20 to 31 gallons per seat per day and 86 to 122 gallons per employee per day.

Table ES.2 Efficiency benchmarks for restaurants

End Use/Benchmark Measure	N	Efficiency Benchmark Range*
TOTAL WATER USE		
Gal./sf/year	90	130 - 331
Gal./meal served	90	6 - 9
Gal./seat/day	90	20 - 31
Gal./employee/day	90	86 - 122

*Developed from combined methods (field studies, audit data, and modeling results)

Hotels and Motels

Table ES.3 shows the comparison data for hotels and motels. The data suggests that an efficient hotel or motel would use about 60 to 115 gallons per day per occupied room for indoor purposes. Concerning cooling use, an efficient hotel or motel would use around 7,400 to 41,600 gallons per occupied room in a year. Efficient irrigation use would involve 16 to 50 inches per year depending on the local weather conditions and the type of landscaping material. An efficient hotel's total water use should fall within a range from 39,490 to 53,960 gallons per occupied room per year.

Table ES.3 Efficiency benchmarks for hotels and motels

End Use/Benchmark Measure	N	Efficiency Benchmark Range*
INDOOR USE		
Gal./day/occupied room	98	60 - 115
COOLING USE**		
Gal./year/occupied room	97	7,400 – 41,600
IRRIGATION USE**		
Inches per year	97	16 – 50
TOTAL WATER USE**		
Gal./year/occupied room	98	39,000 – 54,000

* Developed from combined methods (field studies, audit data, and modeling results)
** Appropriate benchmarks will depend upon local climate.

Office Buildings

Table ES.4 shows the comparable data for office buildings. The data suggests that an efficient office building would use for indoor purposes approximately 9 to 15 gallons per square foot of building area per year. Also, efficient indoor use would involve 9 to 16 gallons per employee per day. Concerning cooling use, an efficient office building would use around 9 to 22 gallons per square foot per day. Efficient irrigation use would involve 26-50 inches per year depending on the local weather conditions and the type of landscaping material. An efficient office building's total water use should range from 26 to 35 gallons per square foot per year.

Table ES.4 Efficiency benchmarks for office buildings

End Use/Benchmark Measure	N	Efficiency Benchmark Range*
INDOOR USE		
Gal./sf/year	62	9 - 15
Gal./employee/day	72	9 - 16
COOLING USE**		
Gal./sf/year	49	8.5 - 22
IRRIGATION USE**		
Inches per year	47	26 - 50
TOTAL WATER USE**		
Gal./sf/year	62	26 - 35

* Developed from combined methods (field studies, audit data, and modeling results)
** Appropriate benchmarks will depend upon local climate.

Supermarkets

Table ES.5 shows the comparable water usage data for food stores. The data suggests that an efficient supermarket would use between 24 to 52 gallons per square foot of building area in a year. Also, an efficient supermarket would use approximately 0.008 to 0.029 gallons per square foot per daily transaction. Concerning irrigation use, an efficient supermarket would use about 30 to 50 inches per year depending on the local weather conditions and the type of landscaping material. An efficient supermarket's total water use would range from 57 to 80 gallons per square foot of building area and 3 gallons per transaction.

Table ES.5 Efficiency benchmarks for supermarkets

End Use/Benchmark Measure	N	Efficiency Benchmark Range*
INDOOR USE (WITH COOLING)**		
Gal./sf/year	38	52 - 64
Gal./sf/daily transaction	38	9 - 16
IRRIGATION USE**		
Inches per year	5	30 - 50
TOTAL WATER USE**		
Gal./sf/year	38	57 - 80
Gal./transaction	38	3

* Developed from combined methods (field studies, audit data, and modeling results)
** Appropriate benchmarks will depend upon local climate.

Schools

Table ES.6 shows the comparison data for schools. Recall that the field study data comes exclusively from high schools while the audit data includes information from schools ranging from elementary to college level. The data suggests that an efficient school would use about 8 to 16 gallons per square foot per year for indoor use. Also, an efficient school would use between 3 to 15 gallons per school day per student for indoor use. Concerning cooling use, an efficient school would use around 8 to 20 gallons per square foot per year. Efficient irrigation use would involve 21.5 to 50 inches per year depending on the local weather conditions and the type of landscaping material. An efficient school's total water use should range from 40 to 93 gallons per square foot per year.

Table ES.6 Efficiency benchmarks for schools

End Use/Benchmark Measure	N	Efficiency Benchmark Range*
INDOOR USE		
Gal./sf/year	142	8 - 16
Gal./school day/student	141	3 - 15
COOLING USE**		
Gal./sf/year	35	8 - 20
IRRIGATION USE**		
Inches per year	132	22 - 50
TOTAL WATER USE**		
Gal./sf/year	142	40 - 93

* Developed from combined methods (field studies, audit data, and modeling results)

** Appropriate benchmarks will depend upon local climate.

RECOMMENDATIONS

The results of this study and the insights gained through the field investigations and data modeling and analysis support the following recommendations for the management of water demands in the commercial and institutional sector of urban water users.

1. A standardized classification scheme of CI customers should be developed by water industry to facilitate both demand planning and evaluation of conservation programs. The existing classification systems are generally inadequate for comparing water use of similar customer categories between different water providers.

2. Meaningful aggregate benchmarks can be developed by collecting additional aggregate data on the size of the CI activity represented by a category. The aggregate measures of size could include the combined square footage of all buildings in the category, total category employment, school enrollment, seating capacity (in restaurants), number of hotel rooms or other aggregate measures of business size in the service area. Benchmark values should be developed by dividing the total category water use by the scaling measure.

3. It is recommended that water agencies institute a routine collection of supplemental data from their CI customers on the size of their business. Only the relevant information should

be collected to minimize the burden on the individual customers. The common measures of business activity (and size) such as the number of employees, square footage of all buildings or number of transactions per unit time should be adequate for benchmarking purposes. Establishment-level benchmarks can be very useful in assessing the conservation potential of individual CI customers. However, the development of meaningful benchmarking measures would require good information on both the establishment's water use and the identification of establishment type and size. Opportunities may exist for partnering with other utilities and agencies to obtain this supplemental data. Many electric and gas utilities and taxing authorities maintain extensive databases on CI customers including square footage, number of employees, sales tax generated, etc. Water agencies should make use of existing data resources whenever possible and should not bother customers with information requests unless accurate establishment level data is not available.

4. Utilities should consider developing efficiency benchmarks for their larger CI end uses. Maintaining this tool may require additional data collection or partnering with other utilities and agencies, however, the net utility cost should be considerably less than blanketing all CI customers for detailed conservation assistance. Whether it be for informing customers of their relative rankings, providing technical assistance, or looking for major savings opportunities, utilities should make better use of benchmarking as a CI conservation targeting tool.

5. Future research should expand to other categories of CI customers and should also assess the actual levels of efficiency in water uses. Establishments for which the individual end uses are verified to be efficient should be included in the calculation of efficiency benchmarks. Without such verification, the approximate range of efficiency benchmarks will remain relatively wide to allow for the analytical uncertainty in deriving the efficient usage values from data distributions.

CHAPTER 1
INTRODUCTION

This report presents the results of the Commercial and Institutional End Uses of Water Study, which has been commissioned by the American Water Works Association Research Foundation (AWWARF). The following team of consultants has performed work on this study:

- Aquacraft, Inc. Water Engineering and Management (prime contractor)
- Planning and Management Consultants, Ltd.
- John Olaf Nelson Water Resources Management

STUDY PURPOSE AND OBJECTIVES

The purpose of this report is to: Summarize and interpret the existing knowledge base on commercial and institutional (CI) uses of utility-supplied potable water in urban areas; present the results of field verification studies in a sample of 25 establishments in five urban areas, provide econometric end use models for various categories of commercial and institutional customers, and develop a set of efficiency benchmarks for five selected CI categories. The specific objectives are:

1. Review and create a database of existing information about CI water use (including information on various end uses where available) and on previously implemented CI efficiency programs.
2. Obtain information on the presence of specific end uses of water use, and quantities of end uses from CI customers within selected categories by examining a sample of CI customers for each of the categories and participating utilities.
3. Identify and develop water efficiency profiles or benchmarks of specific CI customer categories found significant in terms of levels of water use and numbers of customers.

ORGANIZATION OF THIS REPORT

This report is organized into seven chapters. In this chapter, the CI sector is defined including a description of the sources of data and information that were used to meet study objectives.

Chapter 2 presents an analytical review of previously existing information on water use in the CI sector. It describes the quantities of water that are used by the CI sector and identifies principal categories of CI users; presents compilations of existing data on average rates of water use in the CI sector and individual CI categories; provides a discussion of the determinants of CI water demand and describes various measurement and analysis techniques. An associated Appendix (Appendix F) describes the results of available studies of implemented CI conservation programs and examines the potential for the future development of effective conservation programs in the CI sector.

Chapter 3 describes the methodology and procedures used to select five specific CI categories for examination in this study. The five categories that were ultimately selected by the Project Advisory Committee (PAC) include: Office buildings, hotels and motels, restaurants, supermarkets, and schools.

Chapter 4 presents the results of the direct measurement field studies. The chapter describes the selection of the study sites, site visits, data analysis, and results from the five selected CI categories.

Chapter 5 presents the generalized models of CI water use.

Chapter 6 presents the benchmark developed from three sources in this study – direct measurement field studies, audit data, and modeling results.

Chapter 7 includes conclusions and recommendations based upon the results and experience with this study.

Detailed sets of appendices provide supporting data, additional methodology, and discussion.

THE CI SECTOR OF URBAN WATER USE

Urban water supply utilities provide water for most uses that are found in urban areas. Generally, a central water supply system is constructed to deliver water to individual customers through metered connections. Because the cost of serving individual customers depends on their water-use characteristics, water utilities group their customers into various classes that exhibit similar characteristics.[1] Typically, the customers are grouped into residential and nonresidential classes. These broadly defined classes of customers are also referred to as *user sectors*. These main classes or sectors can be subdivided into *subsectors*. For example, the residential sector can be subdivided into single-family, multifamily, mobile home, and other residential subsectors. The nonresidential sector can be subdivided into commercial, institutional and/or governmental, and industrial subsectors. Both the sectors and subsectors can be further subdivided into smaller groups or *categories*. For example, the commercial sector can be disaggregated into such categories as restaurants, hotels and motels, food stores, car washes, and others. Because of the recent emergence of utility-sponsored water conservation programs, these groupings of individual customers now hold an added significance. A useful system of sectors and categories of urban water users would be one that subdivides all customers by both their cost-of-service characteristics to support rate making and their potential for water conservation.

The literature on urban water conservation shows several definitions of the nonresidential sector. The sector that contains the industrial, commercial, and institutional users of urban water is designated as the ICI or CII sector. Where significant industrial customers are not present, the term CI is often used. An alternative acronym, BIG stands for business, industry, and government. The definitions of CI sectors vary between water utility and from study to study. For instance, some agencies define the CI sector as all business accounts in the commercial sector, which may include manufacturing and governmental establishments, while others may separate industrial and institutional sectors. In addition, residential complexes such as apartment buildings, mobile home parks, etc. whose accounts may be registered in the name of a business entity are often considered commercial accounts. For the purpose of this study, the commercial and institutional sector (or CI sector) is defined as a grouping of all nonresidential and non-industrial users[2] of urban water. In particular, commercial users are defined as retailers, wholesalers, other services establishments, and institutional users such as public (or quasi-public) providers of goods and services.

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[1]Many utilities divide customers by meter size, which reflects the hydraulic requirements of the customer connection.

[2]Many small manufacturing businesses have participated in CI audits and may contribute to participation in CI conservation programs in general.

Defining the CI Sector and Categories of Users

The entire CI sector consists of a large number of dissimilar customers, particularly in the way they use water. The combined water use of all CI customers typically constitutes approximately 15 to 25 percent of total municipal water demand and more in some locations. Despite its importance as a sector, CI uses have received less attention than the residential sector in the development of water conservation initiatives nationwide. This is largely due to the heterogeneous nature of this customer sector and a lack of knowledge regarding end uses of water.

The only complete and consistent classification of the CI sector is based on the U.S. Department of Commerce Standard Industrial Classification (SIC). According to this classification, CI establishments are classified within the range of SIC codes 40 to SIC 97. Examples of categories of CI sectors are listed in the first two columns in Appendix Table A.1 by two-digit and three-digit SIC.

The CI sector can be divided into two or more subsectors in most cases. Typically, the CI sector can be broken down into commercial, institutional, governmental, and public subsectors. Each subsector is divided into categories that most frequently represent various types of establishments. The categories with customary names are usually inadequate for a complete coverage of the entire CI sector. Some establishments cannot be classified and are usually grouped under a generic name like "other commercial" or "general commercial".

While the SIC system is convenient for classifying the CI sector as a whole, the groupings of individual establishments within two-digit or three-digit codes may not be helpful for the design and implementation of water conservation programs. It must be pointed out that the inconsistent definition of the CI sectors together with a general lack of information impedes the synthesis of information about CI water use patterns from the literature.

John Boland developed a system of water use types for the CI sector that assigns codes of water use for special purposes to SIC categories at two-, three- and four-digit levels, with a significant fraction of water use for a named special purpose (Davis et al.1988). Water use by employees for sanitary purposes is assumed present in all CI categories; the other nine special purposes included:

1. Sanitary use by residents, students or other defined non-employee population
2. Sanitary use by patrons or general public
3. Food preparation use with food served to employees
4. Food preparation use with food served to residents, students, or other defined non-employee population
5. Food preparation use with food served to patrons or general public
6. Water use for boiler feed
7. Water use as input to production of goods or services including water incorporated in product, not seasonal in nature
8. Water use as input to production of goods or services including water incorporated in product, seasonal in nature
9. Other water uses including vehicle washing, floor and driveway cleaning, etc.

Water use for seasonal purposes such as cooling, air conditioning, and occasional lawn and shrub irrigation was not separately specified, since those uses can be present in any SIC code, depending on the type and location of building.

As of 1997, the SIC system has been replaced by the North American Industry Classification System (NAICS) which coordinates classifications in the United States, Canada, and Mexico. The NAICS codes do not correspond with the old SIC system. It should be noted that the water industry has not integrated the new classification system into general practice.

WATER EFFICIENCY PROFILES

An improved classification of the CI users of water is needed for water conservation planners to be able to develop information on the quantities of water that would be reasonably required to support various CI activities. Such quantities are often referred to as profiles or benchmarks. An example of a *benchmark usage* is the per capita rate of urban water use, which is usually obtained by dividing total annual water production (or the total volume of water delivered to the distribution system) by total population served. Urban water use must be disaggregated into somewhat more homogeneous groups of users in order to obtain meaningful benchmarks for comparing efficiency of water use between utilities.[3]

The appropriate efficiency benchmarks would reflect quantities of water used for specific purposes (also referred to as end uses), that accomplish the same purpose with less water. For example, a toilet can be theoretically flushed with 1.6, 3.5, or 5 gallons of water. These three flush volumes can be combined with the daily frequency of flushing per person to represent *efficiency benchmarks* for the end use of toilet flushing. Although more or less distinct levels of technical efficiency can be defined for some end uses, they do not cover all CI uses, and are often in the form of design parameters that differ from actual performance in accomplishing the purpose of water use.

The lack of benchmark measurements of the quantity and variability of water used for cooling, cleaning, sanitary, and irrigation within categories of similar businesses is an obstacle to designing CI water efficiency programs and to developing reliable estimates of CI water efficiency savings. However, the development of benchmark quantities for all urban end uses would be an enormous task that is not likely to be accomplished in the near future. Furthermore, even if all existing end uses were "mapped out" in terms of their levels of technical efficiency, such knowledge would be of limited use for conservation planners who must judge the levels of efficiency based on total water use of customers within a given customer group.

A practical and meaningful benchmark of efficiency in water use is the rate of water use that takes into account all variables, which affect the observed volume of water use other than efficiency factors. For example, if average water use per school is compared between two cities, it is necessary to take into account such variables as type and number of schools and students, the size of irrigated play fields, swimming pools, type of cooling system, climate, and other "normalizing" variables. Once the contribution of these variables to the observed average rate of use is removed, the adjusted (or normalized) rate can be considered as an indicator of the level of efficiency. One of the purposes of this study is to identify such measures of efficiency for selected CI categories of urban water users.

[3]Disaggregation can also improve the accuracy of forecasting future needs.

CHAPTER 2

ANALYTICAL REVIEW OF EXISTING INFORMATION

This chapter presents an analytical review of previously existing information on water use in the CI sector. This chapter:

- Describes the quantities of water that are used by the CI sector and identifies principal categories of the CI users;
- Presents compilations of existing data on average rates of water use in the CI sector and individual CI categories;
- Provides a discussion of the determinants of CI water demand and describes various measurement and analysis techniques;

In addition, an associated appendix (Appendix F) summarizes results of selected available studies of implemented CI conservation programs and examines the potential for the future development of effective conservation programs in the CI sector.

DATA SOURCES

Three major sources of information have been used in developing this chapter. First, a survey of water agencies was conducted to obtain existing reports, studies, and data on their water sales to the nonresidential sector. The agencies were also asked for information regarding their methods for identifying the categories of CI water users. Second, professional and academic publications were used to synthesize analytical understandings and perspectives on CI water use characteristics. Third, industry reports and documents were also referenced as a knowledge base about the experience of implementing CI water conservation programs.

Utility Data Request

To collect information on the current knowledge of CI water uses, the study team conducted a mail survey of selected water utilities. A cover letter and a data request form were mailed to 140 persons representing water utilities and other water agencies. The list of these persons and their names and addresses was generated from a list of attendees at the Conserv96 conference in Orlando, Florida.

Three items were requested. First, information was requested on the categories established by utilities to classify their nonresidential water customers and the criteria used for classification. The purpose of this request was to identify and develop profiles of significant CI customer categories. Second, data were solicited on the sectoral composition of annual water use[4] and the sectoral shares of total metered water sales in individual water agencies. This item was requested to accomplish three tasks: (a) analyze the share of CI water uses in total metered water use, (b) examine the variability of CI water sales within various CI categories and as a whole, and (c) compile a database of existing information about quantities of CI water uses across the U.S. Third, general information was requested on the characteristics of the utilities' 20 largest nonresidential (excluding manufacturing) water users. Specifically, these characteristics included the types of business represented, the types of end uses present, and their corresponding annual water use. The purpose of this request was to learn more about the correlation between these characteristics and the presence of specific purposes of water use.

Unfortunately, only ten water utilities (7 percent) returned the mail survey forms with some information regarding their records of CI water uses. Although the response rate of this mail survey was low, the information received from water utilities was adequate to help provide an overview of water demands in the CI sector.

Literature Review

In addition to the direct request of information from water utilities, the study team reviewed academic and professional literature for existing studies on the characteristics and databases of CI sectors. Compared with the residential sector, the CI sectors have received limited attention in the literature. One difficulty in comparing the results from different studies stems from the varied definition of the CI sector and its subsectors. Available literature tends to group CI and industrial users into one sector defined as "commercial" or "business" accounts or the "nonresidential sector." Due to the variability in the nature of CI water use purposes, case studies of individual establishments are usually performed in lieu of sector-wide studies.

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[4]Water utilities were asked to provide annual water use data of two sectors, namely, the residential and the nonresidential sectors, in both units of measurement and in percentage of total metered water sales.

Unpublished Reports

Unpublished industry reports and documents commissioned by water utilities were another important source of information. Though some statistics about water use patterns of the CI sectors were found, several case studies of CI conservation programs revealed that many water utilities have little knowledge about their CI customers, even if they have implemented some forms of CI conservation programs. Most of the implemented CI conservation programs have been pilot programs, and represent spin-offs from residential programs. CI conservation programs have typically focused on the provision of water-efficient sanitation fixtures, such as ultra-low-flow toilets (ULFTs) or faucet aerators, which make them, at least on the surface, to appear to be extensions of residential programs. Furthermore, conservation savings in these pilot programs are usually based on estimates from *identified* or *expected* savings rather than on *total realized* savings. The general lack of available recent data and statistics about the effectiveness of existing conservation programs suggests that there is an urgent need to generate knowledge and improve understanding of CI water use characteristics and conservation program effectiveness in achieving water savings.

QUANTITY AND COMPOSITION OF CI WATER USE

The following sections describe and analyze available data and statistics collected from various industry reports and documents, as well as surveys related to water use patterns and trends of CI sectors.[5]

Relative Importance of CI Sector

An analysis of general trends in CI water use in the U.S. is limited by an infrequent and short time series of national level data on CI water use. The U.S. Geological Survey (USGS) compiles the best and most consistent data source for water use at the national level. The USGS has developed national estimates of water use in the U.S. at 5-year intervals since 1950. The

[5]It should be noted that statistics throughout this section are generally site or study-specific.

most recent of these estimates of national water use is for 1990.[6] Table 2.1 summarizes the USGS data on the distribution of public-supplied water[7] by sector.

Table 2.1 shows that at the national level, the total volume of public-supplied water between 1985 to 1990 increased in all sectors except in the industrial and thermoelectric power sectors. The data suggest that increases in water use in domestic, commercial, and industrial sectors lag behind that of public use during the period. The increase in public-supplied water demand comes largely from changes in the public uses and losses sector. Between 1985 and 1990, water use in the category of public use and losses increased by 3.1 percent (or 1,420 million gallons per day (mgd)) of total public-supplied water delivered. The share of the commercial sector decreased slightly from 15.6 percent of total water delivered in 1985 to 15.3 percent of total water in 1990. Water delivered to the commercial sector in terms of volume, however, increased from 5,730 mgd in 1985 to 5,900 mgd in 1990, at an annual growth rate of three percent. Nevertheless, the combined share of the commercial and public sectors accounts for almost 30 percent of total public-supplied water delivered, and is the second largest destination of public-supplied water. The domestic sector, on the other hand, still accounts for more than half of all treated water delivered in the U.S.

CI use varies from region to region. Differences in climate, as well as differences in the economic and social factors, affect the amount of seasonal water use for irrigation and air-conditioning, as well as general cooling water requirements. For instance, the American Water Works Association (AWWA) conducted a survey of 331 large water agencies which estimated that nonresidential users accounted for 44 percent of the total (metered) urban water use (AWWA 1986). An independent survey of 28 agencies in Southern California, on the other hand, estimated that commercial and public uses accounted for 18.8 percent and 5.1 percent of metered urban water use respectively (Dziegielewski et al. 1990). Table 2.2 shows the quantities of CI use in nine cities in Southern California. The CI sector in those cities is responsible for 15 to 30 percent of total municipal and industrial use (M&I) except for Anaheim, where large demands by heavy industry reduce the relative contribution of CI sector to less than 10 percent of

[6]Subsequent to this analysis, the 1995 issue of USGS *Estimated Use of Water in the United States* has become available.

[7]USGS (1990) defined public-supplied deliveries as water provided to users through a public-supply distribution system.

M&I use. Table 2.2 also shows significant fluctuations of CI demands in time with significant growth in some cities.

Table 2.1 Sectoral distribution of public-supplied water delivered in the U.S.

Sector	1985 Deliveries (mgd)	1985 Percent	1990 Deliveries (mgd)	1990 Percent
Domestic	21,000	57.4%	21,900	56.8%
Commercial*	5,710	15.6%	5,900	15.3%
Industrial†	5,730	15.7%	5,190	13.5%
Thermoelectric power	96	0.3%	80	0.2%
Public use and losses‡	4,040	11.0%	5,460	14.2%
Total	36,576	100.0%	38,530	100.0%

Source: Calculated from U.S. Geological Survey. *Estimated Use of Water in the United States*. (1985, 1990).

* Commercial water use is defined by USGS as water for motels, hotels, restaurants, office buildings, other commercial facilities, and institutions. The water is obtained from a public supply.

† Industrial water use includes water used for processing, washing, and cooling.

‡ Public water use is defined as water supplied from a public water supply and used for such purposes as fire fighting, street washing, and municipal parks and swimming pools.

Table 2.2 CI water use in nine Southern California cities*

City	1980 Deliveries (mgd)	1980 Percent†	1985 Deliveries (mgd)	1985 Percent†	1987 Deliveries (mgd)	1987 Percent†
Anaheim	4.22	7.8%	6.15	10.0%	8.66	13.7%
Burbank	5.88	23.9%	5.15	24.8%	4.82	23.6%
Chula Vista	1.62	17.5%	1.68	17.3%	1.62	19.7%
Fullerton	5.21	15.1%	5.41	18.0%	5.41	17.5%
Los Angeles	141.45	26.9%	149.09	24.6%	135.40	--
National City	1.34	26.1%	1.85	27.6%	1.61	27.0%
Orange	6.35	30.1%	7.32	30.2%	--	--
Santa Monica	--	--	3.07	18.6%	--	--
South Gate	1.58	15.4%	2.03	18.3%	2.22	--

Source: Adapted from Dziegielewski, Opitz, Rodrigo (1990), *Seasonal Components of Urban Water Use in Southern California*. Table I-1, Table IV-1, and Table VI-1.

* Commercial use is defined as water use by business establishments and institutions except manufacturing plants. The estimates include some use that is defined as public and other.

† Percent of all urban use in respective cities.

Composition of CI Sector

Water use within the CI sector can be examined in terms of:

- The presence and prominence of individual categories of CI users such as restaurants, hotels/motels, hospitals and others
- The concentration of CI sector use among individual CI users
- The distribution of use by specific end uses such as sanitary use, cooling, and others

The following sections describe the composition of CI water use and describe the typical end uses within the individual categories.

Distribution of CI Use Among Categories

One way to analyze the CI user at the category level is to study the distribution of total CI water use among individual categories of CI users. The distribution of CI use by category could be analyzed in light of the following questions: What is the presence of CI categories in a particular city/service area? How much water does each CI category consume? What are the prominent categories in a particular service area?

Table 2.3 and Table 2.4 provide statistics on water use in CI categories in 12 selected cities based on data for the period between 1992 to 1995 (EPA 1997). It is shown that commercial use varies substantially as a percent of total CI water use, ranging between 23 percent in Portland (OR) to 86 percent in Orlando (FL). The overall weighted average of the commercial share of total CI use among the 12 cities is about 62 percent as shown in Table 2.3. This means that the institutional sector water use accounts for about 38 percent of the aggregated CI sector water use as indicated in Table 2.4.

In terms of the share of all reported use associated with the CI categories, it is evident that a few CI categories dominate total CI use in certain cities. For example, of all the identified CI categories, the car wash class is absent or minor in the distribution of CI water use in Austin (TX), Miami (FL), and Portland (OR). On the other hand, hospitality and offices account for over 10 percent of total CI uses in most of the cities. Also, the communication and research category accounts for almost one-third of total CI use in Burbank (CA), warehousing accounts for about 31 percent in East Bay Municipal District (CA) and Orlando (FL), and over 10 percent in Buffalo (NY) and Santa Monica (CA). Among the institutional categories, the utilities and infrastructure category users dominated in Austin (TX) and Portland (OR), respectively.

Note that Table 2.3 and Table 2.4 data are sorted in descending order of weighted category use, which allows one to clearly see which categories have the greatest influence in overall CI sector use. Based on the weighted average percent share shown in the last column of Table 2.2, the CI category designated as "hospitality" (which includes hotels and motels) represents nearly 15 percent of CI use. A close second, warehousing, represents more than 12 percent of CI use. Warehousing includes significant uses of water for cooling and refrigeration of perishable food products as well as sanitary uses of employees and visiting truck drivers who also use water outdoors for washing trucks and containers. Other significant categories include office buildings, health care facilities and urban irrigation of parks and landscapes in public buildings.[8] The largest institutional category is designated as "utilities and infrastructure" and accounts for nearly 23 percent of CI use, mostly because of high shares for this category shown by Austin and Portland (OR). Health care facilities are the second largest group and account for over 10 percent of CI water use in eight cities. The education category accounts for nearly 6 percent of CI use and is the most consistent category among the 11 cities.

Data presented in Table 2.3 and Table 2.4 also demonstrate the geographic variability of water use for a given CI category. For example, the education category share of total CI use ranges from 0.97 percent in Buffalo (NY) to 11.96 percent in Santa Monica (CA). The share of CI water use of hospitality ranges from 5.5 percent in Portland (OR) to 39 percent in Santa Monica (CA). This variability can be attributed to both the geographic location and the method of classifying the users into each category.

The geographic variability and prominence of a few CI categories in particular cities can also be due to regional economic factors such as commercial policies, employment requirements for particular skills, available resources, climatic conditions, population characteristics and others. For instance, the warm climate conditions in the Sunbelt region fosters not only higher use for irrigation and landscaping, but also contribute to growth in the senior population which spurs the concentration of nursing homes, hospitals, and other healthcare categories.

[8]Landscape water use, particularly in the West and Southwest is often metered separately. At low-use CI sites there is often only one meter. Therefore landscape water use can show up as "irrigation" water as in Table 2.3 and is also embedded in all CI categories to a lesser or greater degree.

Concentration of Use Among Top Users

On the CI user level, one of the major characteristics of CI water use patterns is the concentration of use. It is known that the distribution of use of the CI sector is highly skewed. That is, a significant amount of sales are concentrated in the water use of a relatively small number of customers. For example, a recent citywide CI sector survey performed by the City of Albuquerque (Kiefer et. al., 1998) shows that approximately 80 percent of the total CI water sold is used by only 20 percent of CI users.

CI End Uses

Because water conservation savings are achieved at the end-use level (i.e. at the specific activity and/or apparatus that uses water), it is important to know the purposes for which water is used in the CI sector and to examine the quantities of water for each purpose. This section addresses the CI end-uses by focusing on the following questions: What types of CI end use are present in a particular CI category? How much water is applied toward each end use? What are the significant end uses in a particular CI class?

Compared to the residential sector, the specific types of uses in the CI sector and the relative importance of these end uses in a particular CI category are complex. The variation in the purposes of water use depends on the nature of business and the levels of technology and water use efficiency in different business establishments. Domestic uses in kitchen and bathroom are only some of the types of end uses present in the CI sector. Other uses such as cooling towers, process rinsing, water treatment activities, and landscape irrigation are also present.

Table 2.3 Distribution of commercial water use by category in selected cities (percent of CI sector use)

Commercial Users	Austin TX	Buffalo NY	Burbank CA	EB-MUD CA	Glendale CA	Miami FL	Orlando FL	Portland OR	San Diego CA	Santa Monica CA	St. Paul MN	Santa Rosa CA	Weighted Average
Reporting Year	1992	1995	1995	1994	1995	1995	1995	1995	1995	1995	1994-95	1994	1992-95
Hospitality*	13.26	20.94	11.75	7.94	13.45	17.53	34.86	5.45	34.28	38.55	15.96	28.12	14.80
Warehousing	1.79	10.83		30.77	0.45	6.73	30.94	2.78	0.03		16.87	0.25	12.40
Offices†	13.97	15.81	11.37	7.09	12.78	12.29	9.7	5.69	7.59		13.03	15.4	9.20
Irrigation‡	2.18	5.13		21.94	5.12		0.8	1.57	4.25	10.32	3.12	0.3	6.15
Miscellaneous commercial§						31.05	0.45		0.06		0.46		5.72
Sales**	6.82	18.15	9.36	3.91	3.54	8.29	2.32	2.99	7.23	6.59	11.97	7.54	5.48
Services††	5.64	0.22	0.59	2.61	4.97		0.45	0.75	13.07		0.21	0.43	2.36
Laundries		3.41	3.52	2.53		2.89	2.13	1.10		3.91		5.88	1.73
Vehicle dealers and services	0.90	3.39	0.24	0.59	4.17	0.95	2.11	0.50	2.63	0.57	3.37	4.83	1.15
Meeting and recreation‡‡	0.96		2.48	2.13	9.59	0.26	0.53	0.01	2.17	3.14	4.98	0.44	1.11
Communication and research	0.11	0.06	27.84	0.15	7.77		1.04		2.97	1.43	0	0.26	0.72
Landscape§§	0.05	2.26	1.01	0.42			0.15	1.63				0.3	0.58
Transportation and fuels		1.15		1.40	0.58		0.74	0			0.61	1.12	0.43
Car wash		2.15	1.17	0.38	0.40		0.20		0.77	2.54	1.24	1.23	0.28
Passenger terminals	0.45	1.17	2.31		0.05		0.01	0.30	0.22	0.33	0.16		0.20
Share of Reported CI Use	46.13	84.67	76.64	81.86	62.87	79.99	86.43	22.77	75.27	67.38	71.98	66.9	62.28

Source: Derived from U.S. Environmental Protection Agency (1997). Table 2. Tabular values are in percentages.

* Hospitality includes restaurant/bar, overnight accommodations, and other group shelter.

† Office includes finance, insurance, real estate, and government.

‡ Irrigation includes parks, gardens, botanical, zoological, cemeteries, and open land.

§ Miscellaneous commercial includes warehousing, warehouse-cold storage, and boat dock.

** Sales include grocery stores, convenience stores, and dry goods.

†† Services include miscellaneous repair services, crematories, funeral homes, laboratories, and printing.

‡‡ Meeting and recreation include convention center, recreation and theaters, and amusement parks.

§§ Landscape includes landscape horticultural service, agriculture, soil preparation, crop services, veterinary, equestrian, livestock, poultry, and game propagation.

Table 2.4 Distribution of institutional water use by category in selected cities (percent of CI sector use)

Institutional users	Austin TX 1992	Buffalo NY 1995	Burbank CA 1995	EB-MUD CA 1994	Glendale CA 1995	Miami FL 1995	Orlando FL 1995	Portland OR 1995	San Diego CA 1995	Santa Monica CA 1995	St. Paul MN 1994-95	Santa Rosa CA 1994	Weighted Average 1992-95
Utilities and infrastructure*	32.34	0.67	0.77	1.88	8.49		5.59	73.04	0.98		0.06	2.86	22.76
Health care†	5.83	12.03	16.73	5.62	18.21	11.5	4.8	3.5	10.94	20.43	17.18	16.36	7.32
Education‡	11.14	0.97	10.19	8.30	7.16	7.33	1.55	0.27	11.41	11.96	8.55	11.06	5.88
Church	1.43	0.31	0.67		2.70	1.18	0.70	0.42	1.19	0.21	1.49	2.79	0.73
Non-profit service and org.§		1.42		2.34	0.59		0.76		0.20		0.78	0.50	0.66
Military	2.42						0.02					0.33	0.27
Share of reported CI use**	53.16	15.4	28.36	18.14	37.15	20.01	13.42	77.23	24.72	32.6	28.06	33.9	37.61

Source: Derived from U.S. Environmental Protection Agency (1997). Table 2. Tabular values are in percentages.

* Utilities and Infrastructure include police and fire station, public works/utility, electric steam, natural gas, gas production and distribution, sanitary collection and disposal, construction, fumigating, and septic tank cleaning.

† Health care includes health services, hospitals and nursing homes.

‡ Education includes schools, museums and libraries, colleges/other schools, and social services.

§ Non-profit service and organizations include professional, labor, civic, political social organizations except churches.

** The sum of percent of CI use in each city may not equal 100 percent due to rounding errors.

Table 2.5 through Table 2.10 present an allocation of end uses in hospitals, schools, hotels, commercial office buildings, commercial laundries, and restaurants based on measurements and estimates from water audits of six U.S. water service areas.[9] The tables further demonstrate the complexity and variation in the proportion of water used in each end use as a percentage share of total water use in these CI categories. Note that in certain water-intensive commercial categories such as car wash and laundry categories, water is the primary ingredient of services these categories provide. Therefore, water consumption in these establishments is highly concentrated in one particular activity. For example, the end use of clothes washing in laundry accounts for the range of 81 to 90 percent of commercial laundry water used (Table 2.9).

Water used for domestic purposes, via plumbing devices such as faucets, toilets, urinals, and showerheads, is usually in the range of one-quarter to half of total water use by most CI categories; except for the car wash and laundry categories mentioned above. The combination of domestic and kitchen water use accounts for 80 percent in restaurants in the two service areas listed in Table 2.10. The majority of water use in schools (Table 2.6) is for domestic purposes (49%) and landscaping (37%). The combination of average water use for domestic and cooling uses ranges from 47 percent in hotels (Table 2.7) to 64 percent in commercial office buildings (Table 2.8). Water use in office buildings is concentrated primarily in the restrooms and kitchen facilities. Landscape irrigation is also a significant use in the western sites.

[9] Note that the precise definitions of CI categories are subject to variation in the reference and definition of the study cited.

Table 2.5 End uses of water in hospitals (percent of total hospital use)

General purpose	Specific purpose	Phoenix	Denver	Mesa	Ventura	Los Angeles	Weighted average†
Domestic	Plumbing*	24.33	39.7	22.95	37.87	18.65	27.05
	Kitchen	8.5	4.53	2.86	4.51	6.51	6.04
Cooling	Cooling tower	27.43	7.22	32.63	8.11	31.29	23.66
	Evaporative coolers (single-passing cooling)	5.08	8.8	7.76	na	na	4.88
	Boilers	2.32	3.61	3.25	1.02	0.31	2.24
Process Rinses	Photographic processing	2.00	4.91	13.99	3.42	7.26	5.78
	Product water (miscellaneous rinses)	na	5.43	0.58	na	10.85	3.12
Cleaning	Clean-in place (plant cleaning)	na	4.78	na	na	na	0.89
Sanitation	Sterilizers autoclaves	6.04	4.91	na	16.95	4.65	5.42
	Ingredients cleaning	na	na	na	0.31	na	0.03
Laundry		7.68	12.33	na	8.43	0.5	5.91
Water treatment regeneration		3.42	na	2.4	6.48	16.18	5.22
Landscape		13.16	3.77	9.35	11.59	3.3	8.77
Miscellaneous		0.04	na	4.22	1.30	0.50	0.97
Number of establishments		3	4	2	1	2	12
Average water use per establishment (gpd)		314,640	160,550	154,000	73,330	159,320	172,390

Source: Adapted from *Journal of AWWA*, Vol. 84, No. 10 (October 1992), by permission.

na = information not available
* Plumbing includes lavatory faucets, toilets, urinals, and showerheads.
† The average is weighted by the proportion of each service area in the combined total use of this category.

Table 2.6 End uses of water in schools (percent of total school use)

General purpose	Specific purpose	Phoenix	Denver	Weighted average†
Domestic	Plumbing*	33.14	47.79	43.47
	Kitchen	6.27	5.35	5.62
Cooling	Cooling tower	1.51	5.21	4.13
	Evaporative coolers (single-passing cooling)	0.16	na	0.05
	Boilers	0.80	na	0.24
Process rinses	Photographic processing	2.09	5.30	4.35
Sanitation	Ingredients cleaning	na	2.93	2.07
Laundry		1.92	3.88	3.30
Landscape		54.11	29.54	36.77
Number of establishments		4	5	9
Average water use per establishment (gpd)		36,390	87,110	61,770

Source: Adapted from *Journal of AWWA*, Vol. 84, No. 10 (October 1992), by permission.

na = information not available

* Plumbing includes lavatory faucets, toilets, urinals, and showerheads.

† The average is weighted by the proportion of each service area in the combined total use of this category.

Table 2.7 End uses of water in hotels (percent of total hotel use)

General purpose	Specific purpose	Phoenix	Denver	Ventura	Weighted average†
Domestic	Plumbing*	17.08	30.62	33.72	23.97
	Kitchen	18.31	9.96	na	13.26
Cooling	Cooling tower	0.64	18.43	na	7.49
	Evaporative coolers (single-passing cooling)	0.25	na	na	0.13
Process rinses	Product water (miscellaneous rinses)	na	6.41	3.62	2.85
Sanitation	Ingredients cleaning	4.67	17.25	29.76	12.03
Laundry		16.82	3.10	22.65	12.07
Water treatment regeneration		0.71	na	na	0.37
Landscape		41.32	na	10.25	22.2
Miscellaneous		0.20	14.25	na	5.63
Number of establishments		4	2	1	7
Average water use per establishment (gpd)		202,140	153,070	38,940	131,390

Source: Adapted from *Journal of AWWA*, Vol. 84, No. 10 (October 1992), by permission.

na = information not available

* Plumbing includes lavatory faucets, toilets, urinals, and showerheads.

† The average is weighted by the proportion of each service area in the combined total use of this category.

Table 2.8 End uses of water in office buildings (percent of total office building use)

General purpose	Specific purpose	Phoenix	Denver	Weighted average†
Domestic	Plumbing*	22.35	40.39	37.21
	Kitchen	1.54	na	0.27
Cooling	Cooling tower	56.05	20.97	27.15
	Evaporative coolers (single-passing cooling)	1.77	1.61	1.64
	Boilers	0.68	5.24	4.44
Process rinses	Photographic processing	0.25	0	0.04
	Product water (miscellaneous rinses)	na	0.10	0.08
Sanitation	Cleaning ingredients, containers	0.23	na	0.04
Laundry		1.54	na	0.27
Water treatment regeneration		4.13	na	0.73
Landscape		12.87	21.60	20.06
Miscellaneous		0.13	na	0.02
Number of establishments		13	3	16
Average water use per establishment (gpd)		55,930	261,530	139,150

Source: Adapted from *Journal of AWWA*, Vol. 84, No. 10 (October 1992), by permission.

na = information not available

* Plumbing includes lavatory faucets, toilets, urinals, and showerheads.

† The average is weighted by the proportion of each service area in the combined total use of this category.

Table 2.9 End uses of water in commercial laundries (percent of total commercial laundry use)

General purpose	Specific purpose	Phoenix	Denver	Weighted average†
Domestic	Plumbing*	2.49	3.53	2.92
Cooling	Cooling tower	6.42	0.31	3.95
	Evaporative coolers (single-passing cooling)	1.97	1.58	1.81
Process rinses	Product water (miscellaneous rinses)	na	0.31	0.19
Sanitation	Ingredients cleaning	80.73	89.78	84.38
Water treatment regeneration		8.26	na	4.91
Miscellaneous		0.13	4.34	1.84
Number of establishments		13	3	16
Average water use per establishment (gpd)		76,300	51,850	64,090

Source: Adapted from *Journal of AWWA*, Vol. 84, No. 10 (October 1992), by permission.

na = information not available

* Plumbing includes lavatory faucets, toilets, urinals, and showerheads.

† The average is weighted by the proportion of each service area in the combined total use of this category.

Table 2.10 End uses of water in restaurants (percent of total restaurant use)

General purpose	Specific purpose	Denver	Tri-county, FL§	Weighted average**
Domestic	Plumbing*	27.75	35.33	31.05
	Kitchen	48.48	50.00	49.14
Cooling	Cooling tower	0.10	0	0.06
	Evaporative coolers (single-passing cooling)	3.20	0	1.81
Sanitation	Ingredients cleaning	4.40	0.22†	2.58
Laundry		0.70	0	0.40
Landscape		4.30	2.45	3.49
Other		2.30	12.03‡	6.54
Unaccounted		8.70	0	4.91
Number of establishments		3	6	9
Average water use per establishments (gpd)		7,524	5,800	6,773

Source: Derived from: Black & Veatch (1991). Nonresidential Water Audit Program. Aurora, CO: Black & Veatch. Table 3-17; Southwest Florida Water Management District (1997). ICI Water Conservation in the Tri-County Area of the Southwest Florida Water Management District. Brooksville, FL. Table 7.

* Plumbing includes lavatory faucets, toilets, urinals, and showerheads.

† Included also laundry.

‡ Included also unaccounted use.

§ Tri-county area includes Hillsborough County, Pasco County, and Pinellas County.

** The average is weighted by the proportion of each service area in the combined total use of this category.

VARIABILITY OF CI WATER USE RATES

Heterogeneous customers and highly variable use characterize the CI sector. The variability of CI use can be examined by expressing water use in individual establishments or categories of users in terms of water use per unit, which removes the effect of establishment size, however size or scale might be measured. In cases where sector-wide use is compared between cities, the effect of the distribution of establishment sizes is also important. The total number of customers within a CI category, the number of employees, and total output (or some other appropriate volume of commercial activity) can be used to derive and compare rates of water use per unit and examine potential sources of variability. The unit rates of use are helpful in examining the relative efficiency of use among individual establishments, categories, or the CI sector as a whole in different cities.

Unit Rates of CI Water Use Measurement

Unit Use Per Account

This unit usage rate is obtained by dividing total annual (or monthly) water use in a CI category by the number of active accounts in that category. This measure is easy to obtain from data that are routinely collected by water utilities. It measures the average water use rate by a CI account in a day, and the unit is gallons per account per day (GAD). There are several variations in the literature that are related to this term such as use rate per site (gallons per site per day) or per working day.[10] In this report, GAD is defined as:

$$GAD = (TGD / TA) \qquad (2.1)$$

where *GAD* is gallons per account per day in a category;
TGD is the total gallons used per day in a category;
TA is the total number of accounts in a category.

One problem with this definition stems from variation in the numbers of accounts within a particular CI category from time to time. Further, growth and recession within a particular CI category, influenced by other economic activities such as mergers, acquisitions, and consolidations, may affect the numbers of employees and /or activity, and, hence use, from one year to the other. In addition, the number of accounts per facility is often difficult to compile.

Table 2.11 demonstrates the regional and temporal difference in GADs for the CI sector in Southern California. The range of GADs in these cities is between 219 in Chula

[10]The distinction between GAD and gallons per account per working day (GAWD) calls for an appropriate choice of the unit of measurement in different CI categories. For example, commercial offices and schools are usually in operation only during weekdays (a yearly total of 260 days = 5 working days per week * no. of weeks in operation per year). GAWD will be a more representative measurement. On the other hand, facilities such as restaurants, hotels, and hospitals are usually in operation during all days of a week, then GAD will also equal GAWD and will be a more appropriate choice of unit. In the literature, GAD is most often reported as a measurement for all CI categories because there has not been a correction made for the facilities' work schedules.

Table 2.11 CI rates of water use for selected cities in Southern California

City	Year	No. of accounts	Average use per account (GAD)	Non-manufact. Employment	Average use per employee (GED)*
Anaheim	1980	538	5,822	92,174	34
	1985	914	5,066	111,504	42
	1987	--	--	119,236	60
Beverly Hills	1985	872	2,515	59,589	37
	1987	879	2,632	59,794	39
Burbank	1980	3,018	1,343	48,509	84
	1985	3,056	1,421	54,005	80
	1987	3,041	1,405	56,204	76
Chula Vista	1980	5,515	235	--	--
	1985	4,917	219	--	--
Fullerton	1980	2,428	1,485	43,175	84
	1985	1,683	2,904	42,203	116
	1987	1,401	3,372	41,814	113
Las Virgenes	1985	382	5,093	18,625	104
	1987	--	--	22,302	73
Los Angeles	1980	52,270	1,868	1,433,941	71
	1985	54,912	1,901	1,519,956	69
	1987	--	--	1,554,362	71
National City	1980	1,258	901	21,714	52
	1985	982	1,507	29,478	50
	1987	--	--	30,011	41
Ontario	1987	1,624	1,863	31,100	97
Riverside	1980	--	--	76,757	184
	1985	3,489	4,178	89,102	164
	1987	--	--	94,040	169
San Diego	1980	15,004	3,141	425,901	111
	1985	13,813	4,071	501,194	112
	1987	13,723	3,956	517,537	105
Santa Monica	1985	1,543	1,602	62,990	39
South Gate	1980	1,465	909	14,151	94
	1985	1,599	1,093	13,200	132
	1987	--	--	12,820	146

Source: Adapted from Dziegielewski et al. (1990). *Seasonal Components*. Table IV-I.

* GED is defined by dividing the total gallons water used per day by the total number of employment in an establishment or category.

Vista (CA) and 5,822 in Anaheim (CA). In this range, the highest usage per account is nearly 27 times higher than the lowest value. Further, there are considerable changes in GAD rates in individual cities over time. This implies that factors other than the number of accounts affect CI water use.

When the total number of employees in each city is applied to normalize water use, the variation in usage rates in Table 2.11 diminish. The range of per employee rates is narrowed to between 34 gallons per day in Anaheim (CA) and 184 gallons per day in Ontario; with the maximum-to-minimum ratio of 5.4.

Table 2.12 shows per employee use rates that were estimated by Mercer and Morgan (1973) for establishments designated by two digit SIC classes. The results show that in 1970 the highest water use per employee[11] occurs in the category of arboreta, botanical and zoological gardens (SIC 84) which is imbedded in the services category of Table 2.12. The second highest water use per employee was found in the food preparation and processing industry, which is not technically in the CI sector as defined for this study. The order of magnitude of change in a 2-year span indicates the shortcoming of using this unit as an indicator of water use.

Table 2.12 Estimated water use per employee by broad SIC classification

Category	**SIC**	**1968**		**1970**	
		Acre feet/year per employee	**GED**	**Acre feet/year per employee**	**GED**
Transportation & utilities	41-49	0.390	348	0.040	36
Wholesale & retail trade	50-59	0.860	768	0.097	87
Finance	60-67	0.033	30	0.030	27
Services	70-89	0.226	202	0.228	204
State and local government	92-93	0.217	194	0.242	216

Source: Mercer, Lloyd, and Douglas Morgan (1974). "Estimation of Commercial, Industrial, and Governmental Water Use for Local Areas." *Water Resources Bulletin* 10 (4). 794-801. Table 1.

Per employee rates for more disaggregated categories are shown in Table 2.13 for 22 selected CI categories. These rates of use have been used as library values for the IWR-MAIN (DOS version) water use forecasting software program (PMCL 1995). The table shows use among the two-digit SIC categories ranging from 29 gallons per employee per day in the

[11]Mercer and Morgan (1974) calculated SIC category water use per employee. That is, water use per employee in the ith two digit SIC is equal to the sum of water use by sample and census firms in the ith two digit SIC divided by the sum of employment in sample and census firms in the ith two digit SIC.

wholesale durable goods category to 462 gallons per employee per day in the personal service category. The per employee rates weighted by employment were obtained by dividing the combined water use in all sample establishments by the combined employment. This method of deriving per employee rates compensates for the skewness in the distribution of per employee rates in a sample of individual establishments. The mean establishment GED rate in Table 2.13 is significantly higher than the rate weighted by employment in almost all SIC categories (with the exception of dentist offices). In the case of amusement and recreation services, the skew is so severe that the mean GED is more than ten times higher than the weighted mean. In addition, all categories show high variability of GED rates between the establishments as indicated by the standard deviation.

Because of the high variability of per employee rates within the 2-digit SIC categories, it is impossible to derive benchmark rates of usage at this level of disaggregation. In most categories, 3-digit or even 4-digit SIC disaggregation may be necessary in order to reduce significantly the variability of per employee usage rates within a particular group. Average per employee rates in a in a sample of 1,405 establishments drawn from a six-county urban area of Southern California and in a national sample of more than 3,000 establishments for 3-digit SIC codes are included in Appendix A. The range and standard deviation in per employee usage within individual categories shown on those tables indicate that higher levels of SIC disaggregation continue to show high variability of water use for some categories. For those categories, the use of employment as the "normalizing variable" may not be appropriate because the volume of water used by the establishment depends on the presence of activities or establishment features that are often independent of the number of employees.

Table 2.13 Selected commercial and institutional water use coefficients

SIC	Description	Sample size	Employment weighted GED	Mean customer use, GED	Standard deviation GED
50	Wholesale durable goods	517	29.0	85	492
51	Wholesale nondurable goods	233	86.7	134	409
54	Food stores	90	97.9	194	490
55	Auto dealers & service stations	198	48.9	83	205
56	Apparel & accessory stores	48	67.7	132	302
57	Furniture & home furnish stores	100	41.7	169	169
58	Eating & drinking places	341	156.2	216	553
60	Depository institutions	97	58.9	97	189
61	Non-depository institutions	12	156.4	489	1,702
70	Hotels & other lodging places	197	229.8	740	1,491
72	Personal services	300	462.1	717	1,174
75	Auto repair, services & park.	108	216.6	685	1,805
79	Amusement & recreation service	106	427.1	5,552	30,565
80	Health services	354	90.6	308	743
802	Dentist offices	22	258.7	216	242
805	Nursing home facilities	106	196.7	237	291
806	Hospitals	122	75.4	95	94
82	Educational services	296	115.8	419	1,060
83	Social services	55	106.4	251	568
84	Museums, botanical, zoo, gardens	9	208.0	269	356
86	Membership organizations	45	212.3	257	442
91-97	Public administration	25	105.7	210	282

Source: Adapted from Planning and Management Consultants, Ltd. (1995). IWR-MAIN 6.1: User's Manual and System Description. Appendix D.

Use Rate Per Unit of Output or Size

Another measurement of unit water use is the mean water use per unit of output in gallons per unit of output per day (GUOD). The GUOD formula is written as:

$$GUOD = TGD / TUOD \tag{2.3}$$

where *TUOD* is total units of output per day at an establishment or within a category.

The problem with this definition is that it assumes all output produced requires an equal rate of water use as an input. Another problem with this definition is the difficulty in measuring the quantity of output in most commercial and institutional categories. The GUOD measure is easier to construct in the industrial sector, where numbers of output such as the number of widgets is easily countable.

Table 2.14 provides some examples of average rates of water use in selected CI establishments based on various normalization factors related to output (Miller et al. 1983). The data in Table 2.14 are based on information from surveys of CI establishments conducted during the 1960s (Linaweaver et al. 1966).

Unit Use Per Floor Area

Table 2.14 also shows ten categories that use square footage as the unit for normalizing use. For the CI sector, customer use of water is a significant part of total water use in addition to employee use of water, particularly for customer-oriented establishments such as restaurants and bars, lodgings, schools, personal services, and others. Under these conditions, an indicator of water use by customers is the gross area of establishment.

McCuen, Sutherland, and Kim (1975) used a linear regression to model water use as a function of gross area of department stores. The regression results can be interpreted to suggest that for every one square foot increase in the gross area of the store, water use of the store would be expected to increase by 0.056 gpd for retail department stores. The equation provides a standard error of estimate of 1,520 gpd, which represents a significant reduction from the standard deviation of 3,262 gpd for water use data, and the variability of estimated water use. They argue that it is expected to provide reasonable estimates of water use. Also, Kim and McCuen (1979) used a multiple correlation analysis and a principal components analysis to estimate commercial water demand, which resulted in a coefficient of 0.0147 gallons per square foot of gross area. In another study, Behling and Bartilucci (1992) estimated that the seasonal rate of office building water use is about 0.045 gallons per day per square foot in the fall and winter, and 0.106 gallon per day per square foot in the spring and summer.

Table 2.14 Selected commercial and institutional unit use coefficients

CI category	Unit	Gallons/unit/day
Barber shops	Chairs	54.60
Beauty shops	Station	269.00
Bus/rail depots	Square foot	3.33
Car washes	Inside square foot	4.78
Churches	Member	0.14
Golf/swim clubs	Member	22.20
Bowling alleys	Alley	133.00
Residential colleges	Student	106.00
Hospitals	Bed	346.00
Hotels	Square foot	0.26
Laundromats	Square foot	2.17
Laundry	Square foot	0.25
Medical offices	Square foot	0.62
Motels	Square foot	0.22
Drive-in movies	Car stall	5.33
Nursing homes	Bed	133.00
New office buildings	Square foot	0.19
Old office buildings	Square foot	0.14
Jails and prisons	Person	133.00
Restaurants	Seat	24.20
Drive-in restaurants	Car stall	109.00
Night clubs	Person served	1.33
Retail space	Sale square foot	0.11
Elementary schools	Student	3.83
High schools	Student	8.02
YMCA/YWCA	Person	33.30
Service stations	Inside square foot	0.25
Theaters	Seat	3.33

Source: Crews, James E. and Mary Ann Miller. 1983. Forecasting Municipal and Industrial Water Use. IWR Research Report 83R-3. U.S. Army Corps of Engineers, Fort Belvoir, Virginia.

Determinants of CI Use

The variability of unit rate of use indicators such as GED, GAD, GUOD, within a CI category, across CI categories, and across time and region (given uniform definitions), is a function of economic, climatic, and technological factors.

Economic Factors

Employee/Patron Requirements. The number of employees is a crucial factor contributing to the total demand for water in a particular CI establishment. The definition of employee requirements for water extends beyond the sanitary needs of salaried personnel to include any persons that are regularly present in a business facility, such as students in schools, patients in nursing homes and hospitals, and patrons of business. A large number of employees and patrons results in a larger use of water in domestic uses such as kitchen and toilet uses. Larger employment can also be associated with a larger floor area of an establishment, which may increase the need for other water-consuming equipment such as cooling towers and other end uses. Ultimately, a larger employment requirement tends to reflect a larger scale of services and products provided to the public, generally leading to a larger demand for water.

Growth or Recession of Industry. The impact of economic growth and recession of an industry over time changes the numbers and types of employees and business establishments in a particular service area. If the change in the number of employees and business establishment is not reflected in a proportional change in water usage, there will be a change in GED or GAD over time in a particular CI category. For example, explosive growth in the semi-conductor industry in Boston (MA), San Jose (CA), and Seattle (WA) not only increased the number of employees in those areas, but also the number of auxiliary business services such as grocery stores, laundries, and car washes to support the growth of employment. Then the demand for water in the CI sector of a particular service area will increase, given that other usage remains unchanged. Thus, the forecast of water demand of a particular category or the CI sector depends on the projection of the future capacity of the category or sector.

Price of Water. The pricing of water has been one of the most debated issues in the water resources industry, as well as in academic literature. The design of an optimal rate structure is believed to be important to effective water demand management strategies. The various rate structures debated include marginal rate, uniform rate, increasing block rate, decreasing block rate, seasonal rate, and others. Most of these pricing structures have been studied with regard to residential sector water demand, however, the effectiveness of various pricing strategies for the nonresidential sector has not been settled.

Lynne, Luppold, and Kiker (1978) used a derived demand model to estimate the price elasticity of commercial demand in the Miami (FL) area. The price elasticity was generally low (inelastic) for all groups studied except for department stores. This group was found to have an elastic demand for water at all prices above $0.93 per thousand gallons purchased per month, where the mean price for the sample (including grocery and supermarket, motels/hotels, eating and drinking establishments, and other commercial) was $1.24.

In another study (McCuen, Sutherland, and Kim 1975), water consumption in the CI establishments in general is price inelastic because the water users (employees and customers) are not directly responsible for water costs. In addition, water cost is just a small component of the overall expenses of CI establishments when compared to energy, labor costs, and capital investment. Thus, at least in the short run, a change in water rates will likely have a small impact on most establishments, except those establishments such as car washes and laundries, which use water as a major ingredient of services they provided. The major implication of these studies is that commercial establishments may be more responsive to price changes over the long run.

Climate Conditions

Seasonality. A normalized rate of use in a given CI category in different regions may be different if the weather conditions are different. Seasonality in water use refers to a characterization that describes variation in water use due to weather conditions and other seasonal cycles in business.[12] The components of water use that are affected by seasonality may include landscaping, cooling, and other uses. These uses fluctuate with weather and climatic conditions in different seasons and in different geographical locations. For example, some commercial establishments may use water for irrigation, air-conditioning or dust control during the summer season. Furthermore, some commercial end uses, such as cooling water requirements, are much higher during hotter, drier days, and in hotter and drier climate regions.

A survey study by Dziegielewski et al. (1990) found that 25 percent of commercial use in Southern California is seasonal. The presence of seasonal variation in a CI sector may also depend on the nature of business establishments. Sport clubs, for example, require more water in the summer than winter due to their seasonal business cycles. Table 2.15 reports the shares of seasonal use in selected CI categories by Dziegielewski et al. (1990). Seasonality of water consumption in the CI sectors varies by type of category. For example, seasonal water use

[12] Weather seasonality does not necessarily coincide with business seasons. For example, peak resort demand is in the winter season in Phoenix (AZ) and in Florida.

accounts for 72 percent of water use in sport clubs, significantly higher than that of restaurants (19 percent).

Table 2.15 Seasonal water use in select CI categories

CI establishments	**Sample size**	**Percent seasonal use***
Restaurants (SIC 5812)	9	19.1
Hospitals (SIC 8062)	15	20.1
Laundromats (SIC 7215)	14	22.8
Hotels/motels (SIC 7011)	15	27.1
Colleges (SIC 8221)	7	40.5
Schools (SIC 8211)	8	42.8
Sport clubs (SIC 7997)	6	72.4

Source: Dziegielewski et al. (1990). *Seasonal Components*. Table IV-7.
* Seasonal use determined based on the minimum month method.

Because of climate differences and variation in the cost of water supply and wastewater disposal, the degree of seasonality should be expected to vary regionally (Dziegielewski et al. 1990). As shown in Table 2.16, in Southern California, seasonal use as a percent ranges from 10 percent of total commercial water use in Santa Monica (CA) to 39 percent in Las Virgenes (CA). In seven out of 14 of these Southern California cities, seasonal increase is more than one-third of annual average demand.

Cooling Degree-Days. Requirements for cooling depend on the amount of heat that has to be removed. The number of cooling degree-days is a measure of the amount of heat, which is related to the temperature of the ambient air during the warm season. Davis et al. (1996) studied the effect of cooling degree-days on municipal and industrial water use and found that the elasticities of cooling degree-days were estimated to range from 0.016 to 0.021 for paper and pulp plants, to 0.022 to 0.091 for poultry processing plants. Kiefer et al. (1995, 1996, and 1998) have estimated significant relationships between nonresidential water use and the departure of the monthly number of cooling degree-days from long-term monthly normals. Yet, there is no study of the effect of cooling degree-days on CI water demand only.

Table 2.16 Seasonal water use in the CI sector in selected cities

City	Seasonal use (%)
Anaheim	34.0
Beverly Hills	20.2
Burbank	14.1
Chino	36.6
Chula Vista (Sweetwater)	13.8
Fullerton	38.2
Las Virgenes	39.3
Los Angeles	13.2
National City	17.5
Ontario	30.6
Riverside	37.7
San Diego	38.6
Santa Monica	10.3
South Gate	16.6

Source: Adapted from Dziegielewski et al. (1990). *Seasonal Components*. Table IV-3.

Precipitation. Increases (decrease) in the amount of local rainfall will not only usually increase (decrease) the available supply of water, but will also decrease (increase) the demand for water for the purpose of irrigation and landscaping. In addition, an increase (decrease) in amount of local rainfall will likely decrease (increase) the need for the use of air-conditioning in the summer season, and thus result in the change in water use by cooling towers.[13] Kiefer et al. (1995, 1996, and 1998) have estimated significant relationships between nonresidential water use and the monthly amount of precipitation, as well as departures from long-term normal precipitation.

Technology

The presence, diversity, and efficiency of various end uses in an establishment affect the quantity of water used. For example, a restaurant using icemaking machines is likely to consume more water than a restaurant without an icemaker, other things being unchanged. As another example, office buildings are likely to consume less water than restaurants for a given number of employees and floor size. Water use in office buildings is likely concentrated in domestic fixtures and landscaping while use in restaurants may be primarily in icemakers, dishwashing, food preparation, and others, as well as domestic fixtures and possibly landscaping. Hospital or hotel establishments with the presence of in-house laundry facilities, landscaping, and variations in capacities of cooling and heating will consume substantial amount of water compared to establishments without these facilities.

The efficiency level of technology a CI establishment has adopted could significantly affect the demand for water. For example, a water-cooled icemaker uses a larger amount of water than an air-cooled icemaker. Likewise, a once-through cooling system consumes more water than a more sophisticated recirculating system.

Recent increased interest in conservation has brought about significant growth in the development of water conservation technology. There is considerable evidence proving that an establishment adopting water-efficient technology can significantly reduce the demand for water.

Conservation technologies, which include water-efficient end use equipment such as ultra low flow toilets, and water-efficient practices such as Xeriscaping, have been relatively effective as tools of conservation in the residential sector. Conserving technologies reduce overall demand for water by minimizing volumes of water per usage (low-flow fixtures), or maximizing cycle per usage (recycling). Table 2.17 lists possible water-efficient technologies for selected end uses.

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[13] This situation applies to where a facility automates indoor temperature control that adjusts to daily temperature.

Table 2.17 Examples of CI conservation technologies

End uses	Conservation Technologies
1. Domestic Use	
A. Kitchen	
1) Faucet	Faucet aerators
2) Distilled/drinking water	
3) Dishwasher	Recycle for garbage disposers, automatic shutoffs
4) Ice machines	Air-cooled machine, multiple-pass cooling, recirculating for landscaping
5) Garbage disposers	Garbage strainers
6) Food preparation	
B. Bathroom	
1) Faucet	Faucet aerators, automatic shut-off, infrared faucet, self-closing faucets,
2) Toilet	Ultra-low-flow toilets
3) Urinal	Ultra-low-flow and "waterless" urinals
4) Bathtub	
5) Shower	Low flow showerheads
2. Recirculating Cooling	
A. Cooling towers	Conductivity control, total dissolved solids (TDS) Sidestream filtration, Maintenance of make-up valves Recycling, incorporating sulfuric acid to reduce carbonate scale Ozone disinfection Reclaimed water for water makeup
B. Evaporative coolers	Recirculating pumps Eliminate excessive bleed-off
C. Boilers	Eliminate excessive blowdown, eliminate mixing valve water Ion exchange
3. Once-Through Cooling	
A. Air conditioners	Air-cooled equipment, reduce flow rate
B. Air compressors	Connect to recirculating cooling system
C. Hydraulic equipment	Recycle cooling water
D. Degreasers	
E. Rectifiers	
F. Vacuum pumps	Convert to mechanical vacuum pumps
4. Process/Rinse	
A. Photographic processing	Automatic shut-off, eliminate "tempering" flows; water-efficient equipment timers; conductivity control
B. Product water rinses	Countercurrent rinsing, solenoid valves
C. Ingredient/material rinses	Squeegees
D. Conveyance	Flow-metering, auto-control valves
E. Purification equipment regeneration	
F. Rinse baths	Waterless equipment
G. Lubrication systems	Sequential rinsing, recycling
5. Sanitation	
A. Facility cleaning	Dry extraction carpet cleaning system Automatic shut-off valves, pressure-reducing valves
B. Sterilizers/autoclaves	Flow-metering, control valves Air pressure host
C. Equipment washing	Wastewater reclamation

(continued)

Table 2.17 (Continued)

End uses	Conservation Technologies
D. Vehicle washing	Use a nose nozzle
E. Dust control	Re-use water from another process, e.g. ice machine discharge
F. Container washing	
6. Laundry	
Washing machine	Horizontal-axis washing machine
	Continuous-batch washers
	Rinse water reclamation; wash water reclamation
	Computer-automated control system
7. Irrigation	
A. Spraying	Moisture sensors and timers, rainfall sensors
B. Planting	Xeriscaping, evapotranspiration, drought resistant shrubs
	Recycle, reclamation
C. Decorative water feature	
8. Leaks	Leak detection system
9. Other/Miscellaneous	Recycling
10. Unaccounted Use	Monitoring meters

Source: Derived from Black & Veatch (1989). *Best Available Technologies" Program: Phase 1 Report: Industrial/Commercial Water Uses Conservation Opportunities*. Phoenix, AZ.

LITERATURE SUMMARY

From the review of literature, one may derive a number of conclusions regarding the state of CI water use and consumption. Some particular conclusions are offered below in preparation for the in-depth analyses of Chapters 4 and 5 of this report.

CI Classifications and Data

The systems of classifying CI customers by water utilities are generally inadequate for comparing water use for individual categories between cities. Only a few categories seem to be adequately defined and comparable. These may include such categories as hotels/motels, schools, restaurants, laundromats, car washes, and other easily recognizable types of businesses. Thus, a significant recommendation of this review is to analyze and develop a standard CI customer classification scheme, which will facilitate both demand planning and conservation evaluation activities. The definition and consistency of CI categories is explored in the next chapter for the utilities that participated in this study.

Availability of Water Usage Benchmarks

Because the system of classifying CI customers is not standardized, it is impossible to develop benchmarks from billing records of water utilities for comparing water usage rates for the same categories of CI customers. Other obstacles to developing meaningful benchmarks of CI water use from billing records include:

- The distribution of CI customers by size is usually skewed with a small number of customers accounting for a majority of water use. This characteristic makes the average use of water per customer within a CI category very sensitive to the degree to which water use is concentrated within top accounts. Under this circumstance, the mean use per customer is not a reliable measure of water use. It can vary in time as the concentration of usage shifts and it can differ between cities with different degrees of concentration of use.
- The most appropriate variables for normalizing water use depend on the type of CI category and often cannot be easily measured. The only normalizing variable that is available to all utilities is the number of active accounts within a CI category. Another variable, the number of employees can be obtained from government statistics but it is usually only available in an aggregate form for only a few points in time. The employment data for individual establishments are usually confidential and imprecise. Other measures of size such as the number of meals served in a restaurant or the square footage of a retail store cannot be obtained from secondary sources and require on-site data acquisition.
- In some categories of CI customers demand is concentrated in one or two end uses, and in order to develop benchmarks, both the size of the establishment and characteristics of the main end uses have to be known. Establishments with significant water use for landscape irrigation or cooling fall into this category. Irrigation use is separated for CI customers in a few utilities and embedded in CI use in others.

CHAPTER 3

SELECTION OF CI CUSTOMER CATEGORIES FOR FIELD STUDIES AND MODELING

INTRODUCTION

Because of the size and scope of the CI customer sector, as described in the Chapter 2, this research project was designed to focus in on a selected group of five CI categories. Water use in the five selected sectors would then be studied in detail through the direct measurement field studies and end use modeling components of the research project. Because of this required focus, it was desirable to select five CI customer categories that are present in most service areas and comprise a significant component of total CI demand. This chapter describes the process by which these five CI categories were selected.

To assist with this process, each of the five participating cities provided historic water billing data from their population of CI customers as well as any classification system in use. These billing data were summarized (some of the results were presented in Chapter 2) and then used to develop lists of CI categories and their relative importance in the five selected service areas. The study team then made an initial selection of candidate CI categories and made recommendations to the Project Advisory Committee (PAC) for the final selection. The PAC determined the final list of five categories during a conference call in May 1998.

PARTICIPATING STUDY SITES AND AGENCIES

The five participating study sites and two contributing agencies were selected based upon a willingness to participate in this tailored collaborative study and to contribute to the cost of the research. Because this study was an extension of the Residential End Uses of Water Study (Mayer, et. al. 1999) many of the participating study sites in the two studies were the same. The five participating study sites were:

1. Irvine Ranch Water District, California
2. San Diego Water Department, California

3. Santa Monica Water Department, California
4. Phoenix Water Department, Arizona
5. Los Angeles Department of Water and Power, California

Participation of two of these utilities was sponsored in part by the San Diego County Water Authority and Metropolitan Water District of Southern California, who also participated in the Residential End Uses of Water Study

All empirical research including the direct measurement field studies and end use modeling was conducted in cooperation with the agencies noted above.

CI BILLING DATA AND RELATED INFORMATION

To assist with the selection of candidate CI categories the participating utilities provided 24 months of raw billing data and customer classification data for their non-residential customers. Requested information included: account number, customer class identifier, customer name, customer contact, contact phone number, customer address, customer description fields, meter number, meter size, billing dates, number of days in each billing period, and water consumption in billing periods. All five utilities cooperated with this request and submitted raw data for analysis.

Data Analysis and Results

In order to verify the information on the distribution of CI use among significant categories, the study team performed an analysis of billing records from the five utilities that were partners in this research project.

A complete set of billing records for a period of one year was analyzed including:

- Analysis of CI categories and use in each city independently
- Comparison of CI categories and use across the five sites
- Development of data that can be used to rank the categories according to conservation potential

Three general criteria were used to screen CI categories for each city independently. First, all categories used by each utility were ranked according to *scaled average daily use* per customer, excluding any industrial categories. For a given CI category, this construct is calculated as the average daily use per customer (in gallons per day) multiplied by the fraction of total annual CI use accounted for by customers in the given CI category. The scaled average daily use per account balances the rate of water used by customers in a category with the relative prominence of that category within the total use of the CI sector.

Next, under-identified CI categories were excluded. Under-identified CI categories are those which clearly contained heterogeneous groups of customers such as "general commercial" categories and other catch-all designations and vague SIC groupings such as "miscellaneous retail". Lastly, only those categories that accounted for 1 percent or more of total CI water use were retained. This analysis resulted in the selection of eleven categories to be considered for final consideration by the PAC. These categories included:

1. Irrigation accounts
2. Schools and colleges
3. Hotels
4. Laundries and laundromats
5. Office buildings
6. Hospitals and medical offices
7. Restaurants
8. Food stores
9. Auto shops
10. Membership organizations
11. Car washes

The water use associated with these categories were then compared across all five study sites. Fortunately, the eleven categories listed above were common to two or more of the five participating utilities. However the fact that utilities classify their CI users differently made comparison across study sites difficult and to some degree qualitative. Although the eleven categories are not used and defined similarly in all study sites, they provided an adequate basis for selecting significant categories of CI users for this study.

A comparison of the water use statistics from these eleven categories is presented in Table 3.1. Possible selection criteria included the scaled use measure described above and statistics related to water use variability and seasonality of use. The data for each category were combined across all cities to further characterize water use among and within the eleven categories. The rows of Table 3.1 titled "Logical-weighted average/total" report values for each category relative to CI use across all of the cities that had the common category, and, in essence, treat the categories as belonging to one "virtual" CI sector in one "virtual" city.

All eleven categories make significant contributions to total CI use, and in total likely account for more than 50 percent of CI use (particularly since the types of customer probably comprise a large portion of under-identified categories). These categories also show high variability of use among individual establishments and a significant seasonal component of annual use. These characteristics make them good candidates for targeting CI conservation programs.[14]

Table 3.2 shows the eleven categories sorted by their likely potential for water conservation. The categories are ranked in joint consideration of scaled average use, percent seasonal use, and variation of use among category establishments. If the total category use was used as a sole criterion for ranking, then office buildings and restaurants would be among the top four categories. Their lower rank on stems from the fact that these categories consist of a relatively large number of individual establishments and do not exhibit a high seasonality of use. The top ranked category of urban irrigation represents water use by irrigation accounts, which are becoming increasingly common among utilities.

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14 It is important to note that for individual facilities, other data must be considered to analyze the amount of variability in water use between facilities that is due to differences in water using efficiencies.

Table 3.1 Analysis of selected common CI categories in five study sites

Applicable City	Customer category description	Number of customers	Total 1997 Use (ccf)	Percent of total CI customers	Percent of total CI use	Average annual daily use (gpdc)*	Std. Dev. of avg. annual daily use	Scaled avg. daily use (gpdc)	Percent Seasonal use
	IRRIGATION								
Irvine	Irrigation	2404	6471968	38.3%	30.0%	5517.1	22120.1	1654.9	87.2%
S. Monica	Landscape – commercial	44	21970	2.1%	1.4%	1023.3	1849.6	14.8	52.2%
	Landscape – municipal	86	87539	4.0%	5.7%	2086.0	4589.3	120.3	71.4%
	Landscape – public schools	2	1750	0.1%	0.1%	1793.2	303.9	2.0	63.0%
	Logical-weighted average/total	2536	6583227	30.2%	28.5%	2595.9	22668.8	739.3	56.9%
	SCHOOLS AND COLLEGES								
Phoenix	Schools	632	2066256	2.8%	6.5%	6700.1	10434.9	439.7	57.7%
Los Angeles	Schools	1424	2494943	5.8%	11.8%	3590.5	4454.9	430.8	62.4%
	Colleges and universities	253	876642	1.0%	4.2%	7100.9	10527.9	295.2	52.1%
	Educational services	227	148975	0.9%	0.1%	1344.9	3131.4	9.6	33.7%
San Diego	Educational services	521	1010304	3.0%	4.1%	3974.0	20054.1	230.5	58.3%
S. Monica	Schools	93	70309	4.4%	4.5%	1549.3	2846.3	71.7	29.3%
	Logical-weighted average/total	3150	6667429	4.8%	8.8%	2116.6	25683.5	187.1	58.0%
	HOTELS								
Los Angeles	Hotels and motels	803	2086331	3.3%	9.9%	5324.5	7781.1	535.3	28.6%
Phoenix	Hotel, motel	338	1856730	1.5%	5.9%	11257.5	27854.1	664.8	16.4%
San Diego	Hotels and other lodging places	82	265255	0.5%	1.1%	6629.2	19273.7	91.5	34.4%
S. Monica	Hotel w/dining facility	20	121525	0.9%	7.9%	12452.2	12928.3	997.4	9.6%
	Hotels w/o dining facilities	23	64274	1.1%	4.2%	5726.9	10268.6	241.2	15.1%
	Logical-weighted average/total	1266	4394115	1.9%	5.8%	7112.9	38476.7	414.3	23.1%
	LAUNDRIES AND LAUNDROMATS								
Phoenix	Laundries; commercial	32	81845	0.1%	0.3%	5241.4	6514.2	13.6	10.0%
	Laundry; self service	82	308501	0.4%	0.1%	7709.9	7276.8	75.9	10.6%
Los Angeles	Coin-operated laundries	518	1923703	2.1%	9.1%	7610.6	6353.0	714.6	10.2%
San Diego	Laundry, cleaning and garment services	107	232408	0.6%	9.4%	4451.2	25987.6	46.1	46.1%
	Coin-operated laundries and cleaning	142	399514	0.8%	1.6%	5765.7	4587.3	103.2	12.5%
S. Monica	Laundromats	22	29656	1.0%	1.9%	2762.5	3484.3	53.6	5.6%
	Commercial laundry	2	1627	0.1%	0.1%	1667.1	2073.5	1.8	40.2%
	Logical-weighted average/total	905	2977254	1.4%	3.9%	3289.8	29130.5	129.8	13.3%

(continued)

Table 3.1 (Continued)

Applicable City	Customer category description	Number of customers	Total 1997 Use (ccf)	Percent of total CI customers	Percent of total CI use	Average annual daily use (gpdc)*	Std. Dev. of avg. annual daily use	Scaled avg. daily use (gpdc)	Percent Seasonal use
	OFFICE BUILDINGS								
Irvine	Office	1530	1340990	24.4%	6.2%	1796.2	2844.9	111.6	33.4%
	Office	3	2752	0.1%	0.0%	1879.9	146.7	0.2	91.3%
Phoenix	Office/bank building (non dining, medical, nursing home)	1257	2232526	5.5%	7.1%	3639.7	5550.2	258.6	38.4%
Los Angeles	Non residential building operators	3487	3983665	14.1%	18.9%	2341.2	4298.8	450.0	22.3%
	Logical-weighted average/total	6277	7559933	11.7%	10.2%	1204.4	7576.3	122.8	29.0%
	HOSPITALS AND MEDICAL OFFICES								
Irvine	Medical lab	37	332347	0.6%	1.5%	18407.7	77908.8	283.5	13.4%
Los Angeles	Health services	1407	1458261	5.7%	6.9%	2124.0	4526.5	149.1	12.2%
S. Monica	Hospitals	21	106638	1.0%	6.9%	10406.4	17370.8	733.7	7.8%
	Medical office facilities	64	49541	3.0%	3.2%	1586.3	2127.5	51.7	4.6%
San Diego	Health and allied services, nec	4	2245	0.0%	0.0%	1150.2	1319.1	0.1	51.3%
	Health services	412	253048	2.3%	1.0%	1258.7	2390.7	14.0	41.0%
	Hospitals	36	306436	0.2%	1.2%	17444.0	54847.8	388.6	73.0%
	Medical and dental labs	44	33158	0.3%	0.1%	1544.3	2651.0	2.4	62.8%
	veterinary services	41	12847	0.2%	0.0%	642.1	1083.7	0.3	76.2%
	Logical-weighted average/total	2066	2554521	4.2%	3.9%	1236.5	97059.1	48.2	23.2%
	RESTAURANTS								
Phoenix	restaurant, bakery	1139	2039912	5.0%	6.5%	3670.3	4726.7	238.2	19.1%
Los Angeles	eating and drinking places	4350	3052052	17.6%	14.5%	1437.8	2111.4	211.4	9.0%
San Diego	drinking places	133	42457	0.8%	0.2%	654.2	589.8	1.2	16.9%
	eating and drinking places	1512	1303088	8.6%	5.3%	1766.2	2707.5	100.7	30.2%
	retail bakeries	4	703	0.0%	0.0%	360.2	100.6	0.0	15.6%
S. Monica	restaurant & bars w/ food	206	217727	9.7%	14.1%	2166.0	3720.5	309.0	4.7%
	bakery or bakery w/ deli	4	1759	0.2%	0.1%	901.2	149.4	1.0	8.9%
	bars w/o dining facilities	8	3209	0.4%	0.2%	822.0	405.6	1.7	9.9%
	Logical-weighted average/total	7356	6660907	11.2%	8.8%	905.5	6965.4	80.0	16.1%
	FOOD STORES								
Irvine	Food	156	356538	2.5%	1.7%	4683.7	10830.3	77.4	17.6%
Los Angeles	food stores	1973	1222326	8.0%	5.8%	1269.6	2398.1	74.1	13.1%
San Diego	food stores	231	243385	1.3%	1.0%	2159.2	3941.2	25.4	50.6%
	grocery store	189	40316	1.1%	0.2%	437.1	585.6	0.8	37.7%
S. Monica	Convenience & liquor stores w/ deli	16	7387	0.8%	0.5%	946.1	1463.7	4.6	7.5%

(continued)

Table 3.1 (Continued)

Applicable City	Customer category description	Number of customers	Total 1997 Use (ccf)	Percent of total CI customers	Percent of total CI use	Average annual daily use (gpdc)*	Std. Dev. of avg. annual daily use	Scaled avg. daily use (gpdc)	Percent Seasonal use
	Logical-weighted average/total	2565	1869952	5.2%	2.9%	729.0	11877.1	20.8	19.4%
	AUTO SHOPS								
Phoenix	service station; auto repair	634	278114	2.8%	0.9%	899.0	2442.4	8.0	29.5%
Los Angeles	automotive dealers and service stations	2203	657760	8.9%	3.1%	611.9	1123.9	19.3	16.4%
San Diego	automotive dealers and service stations	4	246	0.0%	0.0%	126.0	245.2	0.0	70.7%
	automotive repair shops	1304	346333	7.4%	1.4%	544.3	1110.1	8.7	35.3%
	automotive repair shops, nec	1	30	0.0%	0.0%	61.5		0.0	40.0%
	automotive services, except repair	89	152213	0.5%	0.6%	3504.9	4123.8	23.7	56.5%
	automotive services, nec	4	3882	0.0%	0.0%	1988.9	1951.9	0.3	63.0%
S. Monica	auto repair, sales, and service stations	194	47067	9.1%	3.0%	497.2	717.3	15.4	6.1%
	Logical-weighted average/total	4433	1485645	6.7%	2.0%	686.8	5463.6	13.5	27.2%
	MEMBERSHIP ORGANIZATIONS								
San Diego	religious organizations	507	221715	2.9%	0.9%	1008.8	1974.1	9.0	50.7%
Irvine	church rate	826	627517	3.6%	2.0%	1559.8	3064.4	31.0	45.4%
S. Monica	Membership organizations	44	16420	2.1%	1.1%	764.8	1734.1	8.3	16.0%
	Logical-weighted average/total	1377	865652	5.6%	1.9%	628.7	4036.7	12.3	46.2%
	CAR WASH								
Phoenix	car wash	85	247814	0.4%	0.8%	5974.7	5784.3	47.2	13.5%
S. Monica	car wash	4	21957	0.2%	1.4%	126962.2	7467.4	162.1	22.4%
	Logical-weighted average/total	89	269771	0.4%	0.8%	3031.1	9445.7	24.7	14.2%

* Gallons per day per customer

Table 3.2 Characteristics of significant CI categories in five participating agencies

Customer category description	Average annual daily use (gpdc)*	Coefficient of variation in daily use (gpdc)†	Percent of total CI use (%)	Percent of CI customers (%)‡	Percent seasonal use (%)§	Scaled average daily use (gpdc)**
Urban irrigation	2,596	8.73	28.48%	30.22%	86.90%	739.0
Schools and colleges	2,117	12.13	8.84%	4.79%	57.99%	187.0
Hotels and motels	7,113	5.41	5.82%	1.92%	23.07%	414.0
Laundries and laundromats	3,290	8.85	3.95%	1.38%	13.35%	130.0
Office buildings	1,204	6.29	10.19%	11.67%	29.04%	123.0
Hospitals and medical offices	1,236	78.50	3.90%	4.19%	23.16%	48.0
Restaurants	906	7.69	8.83%	11.18%	16.13%	80.0
Food stores	729	16.29	2.86%	5.20%	19.37%	21.0
Auto shops	687	7.96	1.97%	6.74%	27.16%	14.0
Membership organizations	629	6.42	1.95%	5.60%	46.18%	12.0
Car washes	3,031	3.12	0.82%	0.36%	14.22%	25.0

* gpdc: gallons per day per customer

† Coefficient of variation in daily use: The ratio of standard deviation of daily use to average of daily use.

‡ Percent of CI customers pertains to CI customers in agencies that have respective category only.

§ Percent seasonal use = [(total annual use - 12 x minimum month use] / total annual use

** Scaled average daily use = average annual daily use in category x percent of total CI use attributed to the category.

An alternative ranking priority may be developed to emphasize the share of indoor uses. Table 3.3 shows a comparison of the eleven categories above based on *Scaled Inside Use Factor* per customer. For a given CI category, this construct is derived as annual non-seasonal use per customer (in gallons per year) multiplied by the fraction of total annual non-seasonal CI use accounted for by all customers in the given CI category. The scaled inside use factor variable balances the total amount of non-seasonal use by the category with the relative prominence of that category within the total non-seasonal use of the CI sector. By ranking according to the scaled inside use factor, the top five categories become: hotels, laundries, office buildings, schools, and restaurants, respectively.

Table 3.3 Alternative rankings of CI customers in five participating sites

Ranking priority	**Initial Table 2.5 ranking**	**Scaled inside use factor ranking**
1	Urban Irrigation	Hotels
2	Schools and colleges	Laundries and laundromats
3	Hotels/motels	Office buildings
4	Laundries and laundromats	Schools and colleges
5	Office	Restaurants
6	Hospital and medical office	Hospital and medical office
7	Restaurants	Car wash
8	Food stores	Food stores
9	Auto shops	Auto shops
10	Membership organizations	Membership organizations
11	Car wash	Irrigation

FINAL SELECTION OF CI CATEGORIES FOR IN-DEPTH ANALYSIS

The list of eleven CI categories and different ranking schemes and recommendations were presented to the PAC and the final five categories were selected during a conference call in May 1998. Of the eleven categories, the irrigation, car wash, and laundry categories are comprised of very specific types of end uses directed at providing specific products or water services. Although the individual customers in these categories display considerable variance in water use, the PAC decided that a study of conservation opportunities for these categories could be narrowly focused and perhaps better served by independent studies.

The auto shops and membership organization categories share similar qualities in that they are comprised mainly of specific purposes (i.e., washing and sanitary uses, respectively). In consultation with the PAC, it was also determined that the scope and intensity of water services in hospital and other health-related settings blurred the distinction between CI and "light industrial" customers. Therefore, the following five categories were selected for further analysis:

- Schools
- Hotel/motels
- Office buildings
- Restaurants
- Food stores

However, these five categories were not selected solely because of the elimination of other categories. To the contrary, these categories represent CI customer types that are common to most cities, and which present a diversity of end uses and therefore a good basis for examining conservation.

Potential Determinants of Demand in Selected CI Categories

Table 3.4 presents a list of variables that may be considered a partial set of determinants or indicators of water demand in the final selected CI categories. As shown in the table, one may identify variables that affect water use of CI customers in general and variables that would be unique to specific CI customer groups. For example, the number of employees and establishment size could be used to explain or normalize water use for each CI category. Furthermore, the presence of restrooms and other sanitary fixtures indicates their effectiveness would be pertinent to most CI establishments.

Other variables listed in Table 3.4 reflect indicators of (1) the specific types of goods and services that are supplied by the five CI categories, (2) the types of patrons that demand these goods and services, and (3) the types of end uses that are used at these establishments. For example, water use at a restaurant may be defined as a function of the number of visiting customers, number of meals served, and the presence and efficiency levels of kitchen fixtures. The other categories have a more complex set of water demand parameters because of the diversity of services and/or features that may be found on the premises. For example, a hotel may have a restaurant on site as well as laundry and spa facilities, all of which will have specific associated water end uses. Similarly, the modern supermarket may offer a variety of products and services distinct from the products found among its aisles. These services, such as hair salons and photo processing, add a different set of end uses than would have otherwise been found and will contribute to a different pattern and quantity of water use at the establishment. Finally, the water use associated with office buildings can represent the use of various establishments and business types typically found on the first floor of the complex. The range of water-using activities in first floor businesses might be expected to differ from the activities present in office space typically found in higher floors.

Table 3.4 Potential explanatory variables and demand indicators for selected CI categories

Common variables	Restaurants	Hotel/motel	Supermarkets	Schools	Office buildings
• No. of employees • Square footage • Price of water/ wastewater • Air temperature • Precipitation • Sales $ • No. of restrooms and sanitary fixtures by type • Presence of irrigation and type of system • Irrigable landscape area • Type of cooling system	• No. of meals served • Seating capacity • Patron counts • Menu/types of meals • Operating hours • Type of restaurant • Types of kitchen operations • No. and types of water using kitchen fixtures • Average meal price	• No. of occupants • Occupancy rate • No. of rooms • Presence of restaurant and lounge • See restaurant variables • Presence of: Kitchen Laundry Swimming pool Spa/sauna Clubhouse/gym • Type of icemakers • Type, number, and volume of water cooling	• Sales • Presence/types of services Deli Meat shop Photo Hair salon Bakery • No. of aisles • Presence of public restroom facilities • Mist sprayers on vegetables • Hours of operation	• No. of pupils • No. of sporting events • Gym seating capacity/ facilities • No. of showers • Presence of swimming pool • Size and types of play fields • Cafeteria/kitchen • See restaurant variables • Hours occupied	• No. of businesses • Type of businesses/ services • First floor businesses • No. of visitors • Water storage facilities • Presence of eating and drinking places • See restaurant variables • Type of cooling installations • Hours occupied

CHAPTER 4
DIRECT MEASUREMENT FIELD STUDIES

INTRODUCTION

Projecting water savings for commercial and institutional customers requires detailed information on how much water is used by the group for various specific purposes. The current state of information on the end uses of water in CI customers remains vague. One reason for this is the highly diverse nature of CI users, which include the wide array of all commercial and institutional establishments. The typical approach has been to perform a water audit of the site, in which a trained individual visits the site and collects information on all water using fixtures and appliances. The auditor then tries to estimate the total daily use for each piece of equipment, water appliance, or plumbing fixture based on interviews with the staff and measurements taken on-site. If done properly, this method can provide good results, but auditing is time consuming, labor intensive, and subject to errors if the information on which the estimates are based proves faulty.

As part of the AWWARF Commercial and Institutional End Uses of Water Study (CIEUWS), a concerted effort was made to determine if the data logging and flow trace analysis technique used in the Residential End Uses of Water Study (REUWS) could be applied to CI customers in order to provide a new tool for use in the audit process. Using this technique on a single-family residential account it is possible to disaggregate demand into component end uses (toilets, showers, faucets, clothes washers, etc.). This is done by collecting a continuous flow trace from the water meter using a data logger, and then identifying each fixture and appliance use with signal processing software. Clearly, the same degree of disaggregation was not anticipated for any but the smallest CI customers since CI use patterns are much more complex than those of residential customers. At the minimum, it was thought that flow trace analysis could provide better estimates of water use by each fixture than monthly or bi-monthly billing data. The researchers anticipated disaggregating at least indoor, outdoor and continuous uses. This, in itself, is a major advantage for the auditor since it reduces the amount of variability that must be accounted for and makes it possible to spot anomalous uses for further analysis.

The objective of the direct measurement field studies portion of the CIEUWS was to combine information obtained from three sources: (1) surveys, (2) water billing data, and (3) flow traces to develop more accurate estimates of where water is put to use in the five selected CI categories. The small size of the sample in the direct measurement field study portion of the CIEUWS limits the ability to generalize from these results to large populations of CI customers. However, the results from the field studies, especially when compared to the larger audit group, provide a good indication of the expected range of demands within each end use category and provide detail about variety of demands which may be found in these five categories of CI customers.

PROCEDURE

Because the primary focus of the CIEUWS was on the modeling effort, the direct measurement field studies were limited to collecting data from 25 commercial and institutional sites spread across the five participating utilities. Each utility was given a set of criteria, and asked to select five customers from their population of CI customers – one from each of the five selected CI categories: hotels, high schools, restaurants, office buildings, and supermarkets. Once these sites were selected, technicians visited each of the sites, obtained historic billing records from the utility, conducted an on-site audit, and installed a data logger to collect a flow trace from the water meter. During the initial visit, on-site personnel were queried and the site was inspected for prospective sub-meter locations.

The data were carefully analyzed and a detailed end use report for each of the 25 study participants was developed. The final research report contains only summary results from the direct measurement field studies, but to preserve the privacy of study participants copies of the individual site water use reports may only be available through AWWARF.

Selection of Study Sites by Utilities

In February of 1998 a set of selection criteria were sent out to the five participating utilities to assist them with selecting study sites for each of the five categories of CI customers included in this study. Each utility was requested to locate one customer from each category who would be willing to participate in the study. The small size of the sample being studied made it impossible to make it representative of the entire group so participants were selected based on how well they matched the criteria and their willingness to participate. In several cases it proved impossible to find willing participants who also met the selection criteria. In those cases the willing participants were used irrespective of the criteria.[15] The practical effect of this was that many of the sites were much larger than originally planned, which led to a reduction in the resolution of some of the flow trace data.

The process of locating willing participants proved more difficult than anticipated and the process continued through the summer of 1998 even as the field studies were being conducted. With the exception of the high schools, sites had been selected for all categories by September. Work on the selection of high schools was not complete until December 1998 and only four schools were found which could participate.

Site Visits

Most of the 24 CI study sites were visited once during 1988. Each site visit included installation of a data logger on the site's water meter(s), a meeting with the site superintendent or building manager to discuss water use at the site, and an detailed inventory of all water using fixtures and appliances on-site. It was found that water use at many of the smaller sites could be disaggregated from the flow trace obtained from the main meter and the information obtained during the site visit, so sub-metering was not required.

The original project work plan called for use of the main flow trace data to disaggregate water use at the smaller sites, and to attempt to supplement the main traces with installation of sub-meters at the larger sites *where this proved practical.* Experience in the field quickly showed that installing any device into the plumbing systems of large CI customers is difficult and expensive in most cases. Water pipes where sub-meters could be installed were typically inaccessible, or the pipe network was designed in such a way as to require numerous sub-meters. Facility managers were generally cooperative with the auditors, but often made it clear that they had no interest in participating in any monitoring program that might temporarily shut off the water supply.

[15] The only case in which it proved impossible to obtain a study site was for the high school in San Diego. In that case the City was unable to locate a school which had compatible meters and was willing to participate in the study. Many of the schools had old mechanical water meters that are incompatible with the data logger equipment used for the study.

Site Visit Techniques and Procedures

During the data collection portion of the direct measurement field studies, each CI customer was first visited in order to install the data logger on their water meter(s) and record the flow through the water meter for a period of time. With data logging technology now available, precise data on where water is used can be collected in a simple non-intrusive manner, directly from the water meter (DeOreo, Heaney, and Mayer 1996; Mayer and DeOreo 1995; Mayer 1995; Dziegielewski et al, 1993). Each logger is fitted with a magnetic sensor that is strapped to the water meter of each study site. As water is used at the site, it flows through the water meter causing the internal magnets of the water meter to spin. The sensor picks up each magnetic pulse as water moves through the meter and the logger counts the number of pulses detected and stores the total every 10 seconds. The logger has sufficient internal memory and battery life to record for more than 14 days at the 10-second interval.

Using the physical characteristics of each specific brand and model of water meter, the magnetic pulse data is transformed into an average flow rate for each 10-second interval. This flow trace is precise enough to detect the individual flow signatures of water using equipment and appliances (such as clothes washers and cooling towers), and plumbing fixtures in the building, and that of the irrigation system. Using a custom signal processing software package called Trace Wizard, each flow trace was disaggregated into the identifiable component end uses.

The loggers used in this study were the Meter-Master 100EL manufactured by the F.S. Brainard Company of Burlington, NJ. The Meter-Master 100EL logger, shown in Figure 4.1, offered the essential combination of data storage capacity, water resistance, and ease of use.

The basic assumption behind the data logging system in that the water meter is accurately recording flow volume. The logger is not truly measuring flows, but rather recording the movement of the magnets that link the meter to the register and spin as water flows through the meter. The logger records the number of magnetic pulses counted in a 10-second interval and once the data is downloaded, the data logger control program automatically converts the pulse count into flow using the exact specifications of each water meter. Most of the water meters used in this study provided resolution of between 20 and 80 magnetic pulses per gallon. When the logger is downloaded, the logged volume is compared to meter readings taken at the time of installation and removal to check the accuracy of the flow trace.

Each logger was initialized to local time and synchronized to the watch of the analyst, who was the member of the research team who was responsible for performing the site audit. The synchronization process allowed the analyst to record the precise time of events noted during the visit which were then compared to data obtained from the flow trace.

During the field trip all of the loggers were installed on the first day of the visit. Once this was complete a second visit was made to each site in order to interview the building manager and catalogue the water using fixtures present in the building. The technician completed a detailed site survey during this visit and noted the presence of water using equipment, appliances and fixtures, building data, occupancy, irrigation systems, and other water using devices. During each site various appliances were operated and the time was noted down so that the flow trace could later be inspected for a signature.

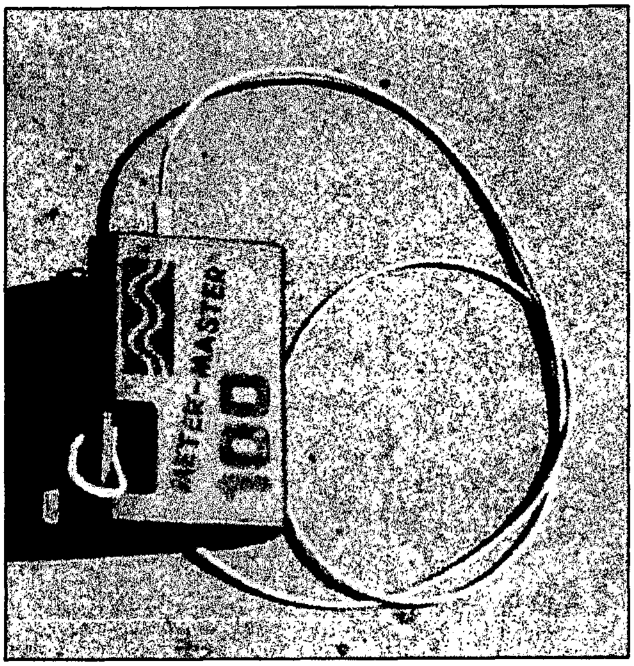

Figure 4.1 Data logger used in this study

Possible locations for sub-meters were also sought during the site visits. There were many obstacles to sub-metering encountered. Finding accurate plumbing plans or individuals that knew about the plumbing was a major problem. Even where plans were available, it was rarely possible to find access points that would allow meters to be installed in a practical manner. Even where access was available, in many cases the actual lay out of the pipes made it impossible to locate a meter where the desired water use would be registered. For example, a logical place to sub-meter would be the laundry rooms in the hotels. These were frequently fed from several directions with piping built into the walls. In none of the hotels was it possible to locate a place where a single meter would register all water use in the laundry, and could be installed without disrupting the operations of the facility to an unacceptable degree.

There were only three sites found where it made sense to employ sub-meters. The two La Quinta Inns (in Phoenix and Irvine) had plumbing lines that were ideally suited for sub-metering. Tiers of rooms are fed from separate ¾" hot and cold supply lines which come off of distribution lines in the attic. These were easily accessed and required only small meters. Each pair of meters supplied a group of from 4 to 8 rooms. The University High School in Irvine also had an ideal system. There, each set of bathrooms was supplied from a single cold water line that entered through a amply sized janitor room. A single 1" meter could then be used to monitor all water use for the bathroom. With the exception of these sites, while it would have been theoretically possible to install more sub-meters, it would have required much more time and money than was available for this portion of the project.

Data from the sub-meters were found to give highly detailed information about the end uses at each specific site, and showed that when sub-metering is possible, more detailed end use data can be obtained using data loggers and flow trace analysis techniques. The project experience shows that sub-metering would make most sense in a detailed study of a few sites over a longer period of time. Such a study could justify the cost of the installation.

Once all the site visits in a particular city were completed, the technician returned and removed the data logger from the water meter, typically after a recording period of 5 days. The data from each logger were downloaded to a laptop computer, the volume recorded by the meter and logger were compared and verified, and the data were stored for analysis.

Data Analysis

A complete data set from each site consisted of billing and customer information supplied by the utilities, site survey data obtained during the sites visits, and flow trace data obtained from the water meter(s) during the site visit(s). These data were analyzed and the results combined to create as detailed a picture as possible of the water use at the site over the year of record.

The fundamental goal of the analysis was to derive good estimates of annual water use at each site for three large categories: indoor use, outdoor use and continuous uses. Indoor use included all domestic sanitary, process, mechanical equipment, cleaning uses, and periodic leaks; outdoor use included irrigation, pool filling, driveway/patio washing; continuous use included leakage and cooling water demand that never ceased during the data logging period. It was also desired, whenever possible, to disaggregate the indoor uses into individual end-use categories such as toilet/urinal flushing, sinks, showers etc.

Use of Billing Data

Billing data were used to determine the annual, monthly and seasonal water use at each site. Some sites had irrigation meters which allowed accurate disaggregation of indoor/outdoor use to be made directly from the billing data. In most cases, however, the billing data included water used for indoor and outdoor purposes and data from the recorded flow traces were used in conjunction with billing data to estimate the indoor/outdoor use split. An example of a typical monthly analysis performed for the direct measurement field studies can be seen in Figure 4.2, which shows the total monthly water use for a small office building. The increase in water use during the irrigation season at this site is evident in the March through November data.

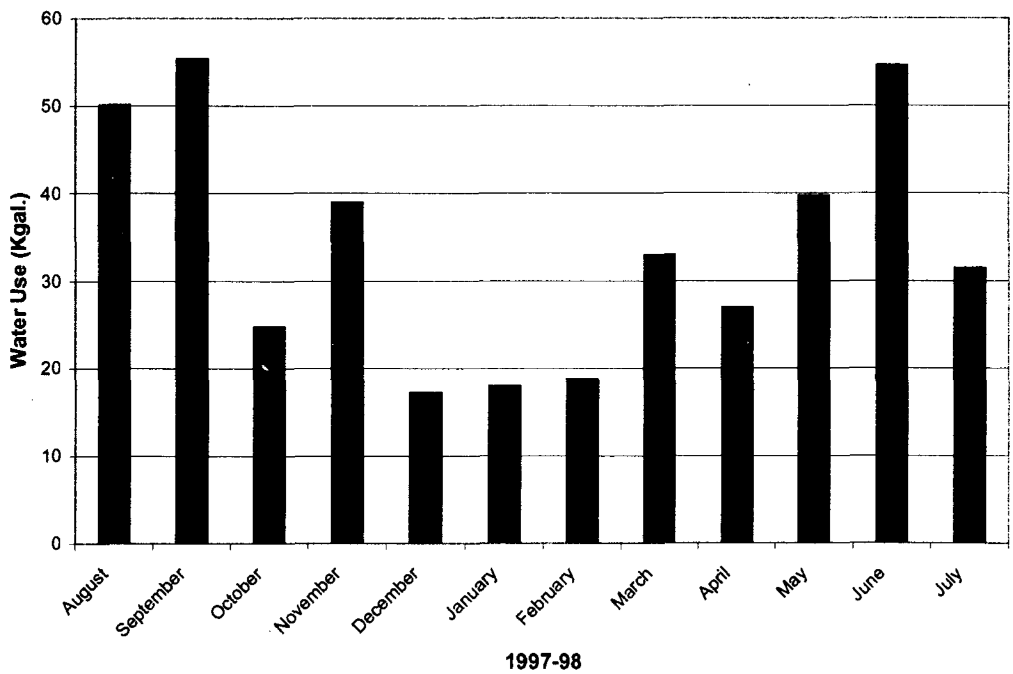

Figure 4.2 Example of monthly use pattern in an office building with irrigation

Flow Trace Analysis

Overview. It is often inadequate to determine important use parameters such as indoor and outdoor use or cooling demand using only monthly or bi-monthly billing data. In many locations both irrigation and cooling water use occur throughout the year making estimates of these end-use categories difficult when based on periodic or seasonal use data.

A goal of the CIEUWS was to use a combination of billing data and information from water audits to derive end-use estimates using statistical approaches pioneered in the electrical industry such as conditional demand analysis. As a secondary matter, the study also sought to use flow trace data, obtained from a customer's water meter, to assist with the disaggregation process. It was shown in the Residential End Uses of Water Study (REUWS) that in single family homes flow trace data could be disaggregated down to the level of individual toilet flushes, showers, irrigation events and clothes washer cycles.

There are two main reasons for the success of this technique in residential customers: the water meters provide high resolution (up to 120 pulses per gallon), and in a single-family home the vast majority of use events are discreet rather than occurring simultaneously with several other uses. This allows the data logger to pick up very small flows and insures that the flow trace will have sufficient resolution to show the true flow patterns of the individual fixtures and appliances in the home. The second essential feature that allows the successful disaggregation of water use is that not too many events occur at the same time. In single-family homes the majority of all events occurred by themselves as single flushes, washing machine cycles etc. Many additional events were mixed with small faucet use or toilet flushes that could be identified as separate events by the software used for the analysis. A small minority of events were clearly a mixture of several events which required that the analyst make a judgment call on how best to disaggregate the event, or whether to place them into the "unknown" or "miscellaneous" category. Generally, in single-family residences the disaggregation from flow trace data occurred with a high degree of confidence about the accuracy of the results.

As the water meters get larger and more simultaneous uses of water are occurring it becomes more difficult to use a single flow trace to disaggregate water use behind the meter. However, even in the largest meters it is possible to accurately identify indoor, outdoor and continuous uses. In smaller customers, with correspondingly smaller water meters, it was also possible to identify many individual indoor water uses.

Analysis Process. The analysis of the recorded flow traces aimed to generally characterize the water use at the facility and included the determination of daily, hourly, and peak instantaneous water use. Where possible peak indoor and peak outdoor use was separated. The daily use during the logging period was compared to the average daily use obtained from the historic billing data in order to determine the degree to which the logging period was typical of the recent annual use. Then the flow trace was examined in detail in conjunction with the information obtained from the site survey in order to attempt to identify specific water uses occurring at the site. In some study sites a high degree to detail was available from the flow trace with little or no judgement or interpretation required. In other cases it was impossible to use the flow trace to disaggregate water use beyond the three major categories. In some cases end uses could be seen during a portion of each day, which were then used to estimate end uses during the remainder of the day when use was masked by large continuous uses.

At three sites, sub-meters were installed to separate water use in a portion of the building. Flow trace data were recorded from these sub-meters which yielded information on end uses which could then be extrapolated to the rest of the facility. Where multiple meters were present, the simultaneous flow traces were combined to create a virtual single flow trace for the facility. This occurred in the hotels, where separate meters were installed on the hot and cold water lines. Each logger gave either the hot water or cold water portion of the event (such as a shower or bath). The entire event required the combination of both flow traces.

Figure 4.3 shows a two-hour section of a fairly simple flow trace recorded from a small office building. A constant flow of approximately 3.5 gpm is evident across the entire two-hour interval, which is due to leakage. There are many toilet and urinal flushes, characterized by their high flow rate and short duration and smaller faucet uses seen as well. In this trace, the entire flow trace could be broken down into the desired end uses without difficulty.

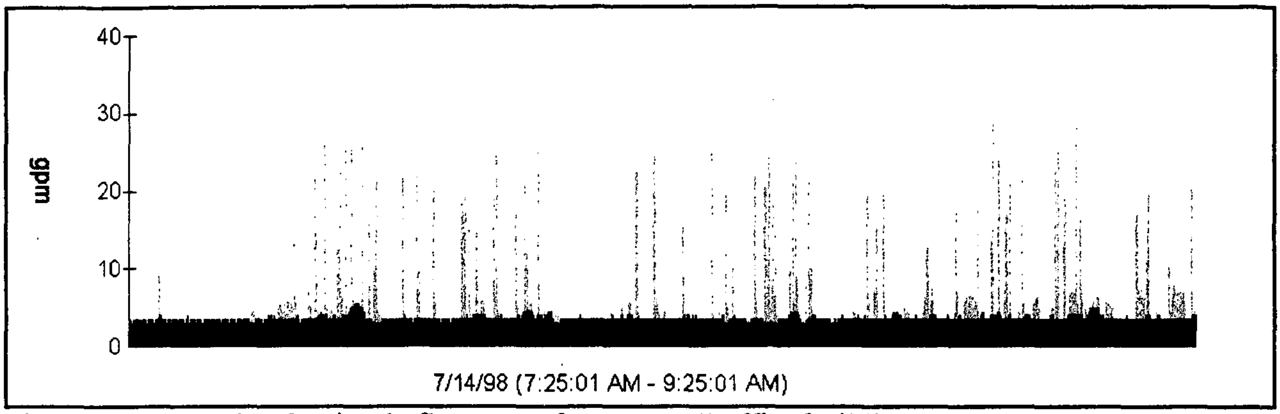

Figure 4.3 Example of a simple flow trace from a small office building

A more complex flow trace taken from a large hotel is shown in Figure 4.4. In this flow trace, recorded from a large meter, the flow rate interval is 25 gpm. This means that because of the low ratio of magnetic pulses to gallons each pulse in a ten-second interval represented a flow of 4.2 gallons or 25 gallons per minute. When meters provide a single pulse for many gallons the flow appear as multiples of that flow, and small events are averaged into the overall pattern. When large volumes pass through the meter, as is the case with this large hotel, all that is seen is a series of step flows. These can reveal very large or continuous uses such as irrigation or cooling use, but no individual uses for showers, toilets or sinks etc can be discerned. This is why the selection criteria were sought to limit the size of the facilities logged.

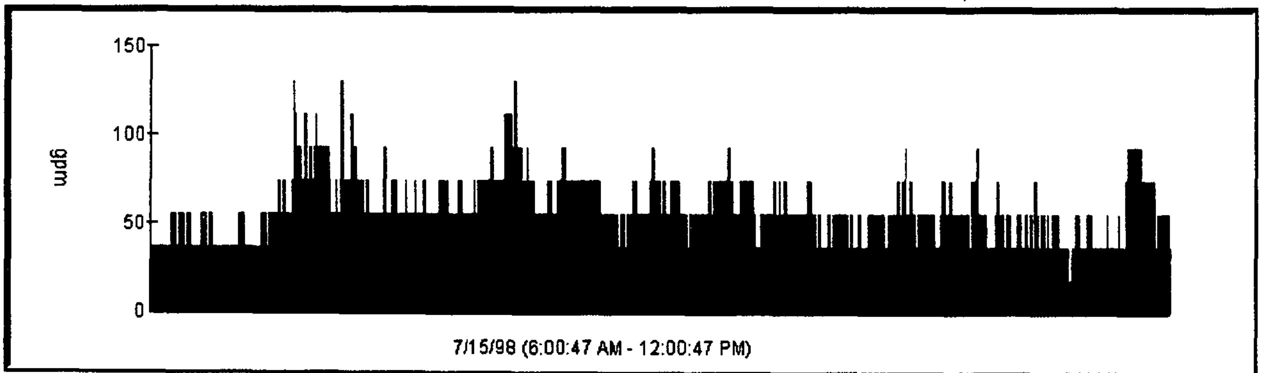

Figure 4.4 Example of flow trace from large hotel

A portion of a flow trace recorded from a specially installed sub-meter is shown in Figure 4.5. The sub-meter was installed on a cold water line feeding 4 rooms at a La Quinta Inn (a second meter was also installed on the hot water line). This figure shows toilet flushes, which are the 4-5 gpm events, the lower flow sinks and the cold water portion of showers. Total room use was determined by adding in the simultaneous trace from the hot water line. The manager provided researchers with occupancy information during the logging period, so from this sub-meter trace it was possible to make good estimates of daily use per occupant, which could then be applied to the remainder of the hotel.

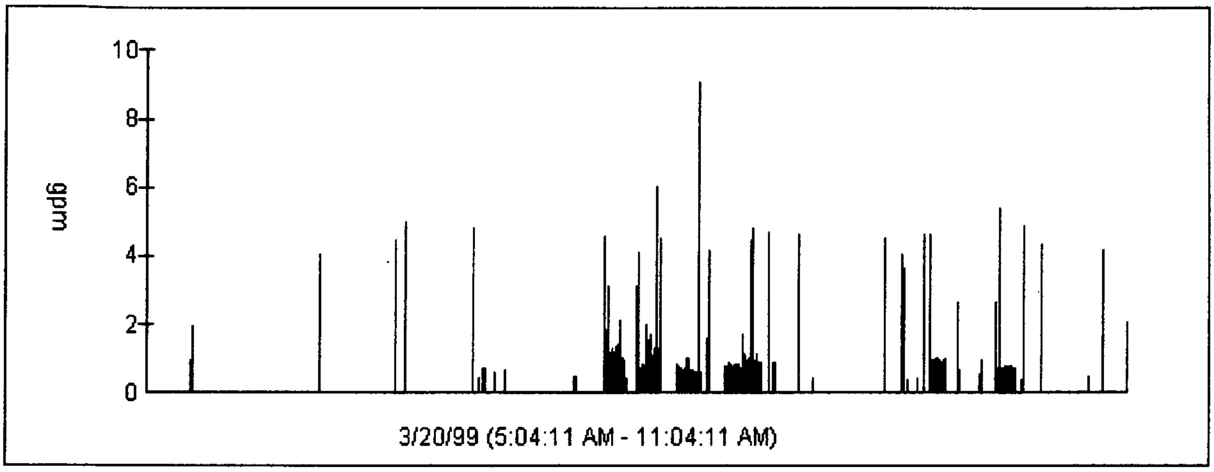

Figure 4.5 Cold water use in 4 sub-metered motel rooms

A portion of a flow trace, which contains irrigation and cooling water flows, is presented in Figure 4.6. This trace was recorded from a large office, but since the irrigation occurred late at night (1:00-4:00 a.m.) and the volumes and flow rates were large (20-80 gpm) it stood out clearly. Refilling of make-up water for the cooling tower caused the small green spikes that can be seen before, after and on top of the irrigation event.

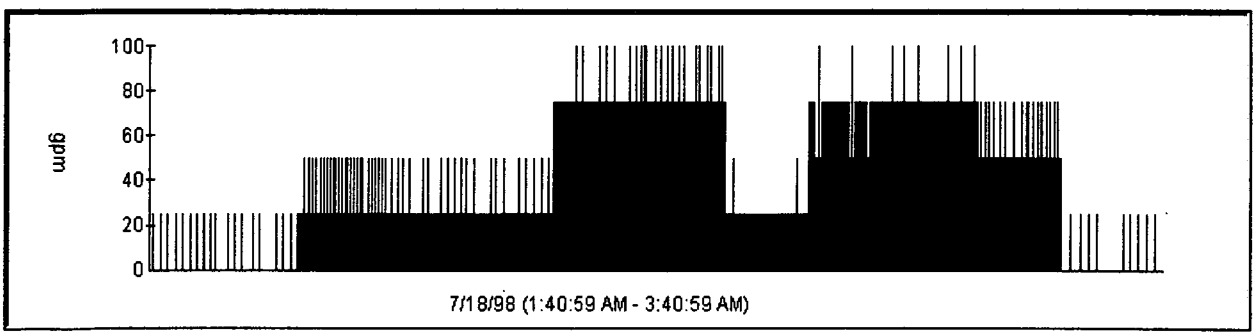

Figure 4.6 Irrigation and cooling use in large office (nighttime)

Summary Analysis

After the flow traces from an individual site were analyzed, daily estimates were made for all of the identified categories during the logging period. These daily estimates were used in conjunction with the billing data and other information collected in the site survey and discussions with the building manager to create estimates of average annual use for each of the identified end-uses. These annual use estimates were made both in terms of simple volumes (gallons per year) and normalized on the basis most appropriate to the type of customer. A summary table was prepared for each customer and included in the individual water use reports. This chapter provides summaries for each category of customer with notes on individual customers as necessary.

RESULTS

The detailed information collected from each site was assembled into a set of 24 detailed individual water use reports. Much of the information that was obtained through data logging such as daily, hourly and instantaneous demand patterns, is of interest, but is not directly related to the main objectives of this research report. The purpose of this section is to provide a summary of the findings that are relevant to the analysis of the annual average day end use patterns of each of the CI institutions. This section also provided information on as many of the end use modeling variables as possible so that these results could be use for calibrating and evaluation the results of the conditional demand analysis modeling.

Office Buildings

General Information

Five office buildings were visited during the study. Table 4.1 shows the basic site information about each of the offices. The original plan was to limit the sites to offices of no more than 15,000 square feet, but as can be seen from the table the size of the buildings ranged from 8,800 to 186,000 square feet. It was impossible to distinguish individual indoor events in the larger buildings, but disaggregation of the use in the smaller buildings was possible to a great extent. Some of the information on the total number of offices and persons working in the buildings was not known by the owners and so was reported as unknown.

All of the sites listed in Table 4.1 were used for standard office purposes except for the clinic building which contained a pediatrician's office, a reproductive health clinic, and an optometrist's office. The office buildings in Irvine, Los Angeles, and Santa Monica were commercial for-lease office buildings, and the San Diego building was occupied by a government agency.

Table 4.1 Size and occupancy of field study office buildings

	Irvine	**Los Angeles**	**Phoenix**	**San Diego**	**Santa Monica**
Type	General	General	Clinic	Govt.	General
Meter size (in)	2	4	2	1.5	4
Flow trace resolution	High	Low	High	High	Low
No. of housed businesses	unknown	70	3	1	unknown
No. of floors	4	6	2	3	11
No. of workers in building	unknown	650	Unknown	110	unknown
Building area (sq. ft.)	57,785	176,500	10,000	8,800	186,000
Irrigated area (sq. ft.)	23,500	4,000	2,400	100	5,000

Annual and Seasonal Use

Billing data for the sites were first analyzed to determine the total annual water use. This information is provided in Table 4.2. These data represent total water use for each site and have not been normalized on the basis of either area or occupants. The seasonal water use was estimated from the billing data using the average winter consumption method, which extrapolates the minimum month (or bi-monthly) use over the entire year and classifies this as non-seasonal use. Seasonal use is the difference between the non-seasonal and total annual use. Seasonal use normally includes increased water use for cooling and irrigation during the summer. It should be kept in mind that in the warm climates of the study sites there is still significant cooling and irrigation use during the winter months, so non-seasonal use cannot necessarily be taken as equivalent to *indoor* use.

Table 4.2 Annual and seasonal water use at field study office buildings

	Irvine	Los Angeles	Phoenix	San Diego	Santa Monica
Total annual use (kgal)	2,039	10,455	406	374	3,903
Average daily use (kgal)	5.6	28.6	1.1	1.0	10.7
Non-seasonal use (kgal)	562	7,423	210	374	2,694
Seasonal use (kgal)	1,477	3,032	198	0	1,209

Logging Data

Data loggers were installed on the water meter at each office building in order to collect continuous traces of the flow at the site. Each of the flow traces was analyzed, and to the extent possible, end use information was disaggregated.

Table 4.3 shows the daily and peak instantaneous water use at each office during the logging periods. Average daily use during the logging period did not differ much from the average daily use calculated from the billing records and shown in Table 4.2. The only exception was the Irvine building, which had a leak during the logging period.

Table 4.3 Water use patterns at field study office buildings during data logging periods

	Irvine	Los Angeles	Phoenix	San Diego	Santa Monica
Logged average daily use (kgal)	12.4	21.4	1.2	1.2	8.3
Billed average daily use (kgal)	5.6	28.6	1.1	1.0	10.7
Indoor peak instantaneous demand (gpm)	67.7	100.0	11.5	20.3	22.8
Outdoor peak instantaneous demand (gpm)	97.6	125.0	20.9	3.0	24.5
Length of flow traces (days)	9.8	4.9	2.6	2.6	7.7

Disaggregation of Flow Traces

A brief description of the results of the attempted disaggregation of water use at each office is provided below. Each site is discussed with respect to the level of detail revealed by the flow trace analysis of indoor, outdoor and continuous uses.

Irvine Office. This site had a 2 inch water meter which provided good resolution to the data logger and made it possible to disaggregate and identify the majority of the indoor uses at the site. Toilet and urinal flushes and a large leak constituted the majority of all indoor use at the building. The only other observed indoor uses were for faucets in bathroom and kitchenette sinks and utility sinks in the janitor closets.

The majority of water use at the Irvine office building was for outdoor irrigation. Outdoor use was separately metered which made it possible to obtain direct measurements of outdoor use from the billing database. During 1997, a total of 2039 kgal were used at this facility - 562 kgal (22 percent) for indoor uses and 1477 (78 percent) for outdoor use, primarily irrigation.

The data logger was placed on the water meter serving indoor purposes at the site and a continuous demand of approximately 3.33 gpm was observed during the entire logging period. This demand was probably not due to any process use within the building. There were no processes identified during the site visit and billing records show that historical indoor demands are closer to the disaggregated indoor uses rather than the total of the indoor and continuous uses. The historical average daily indoor use was 1540 gallons per day (gpd) and the logged indoor uses was 1971 gpd. The continuous use identified from this trace was appears to be due to a continuous leak somewhere in the building's pipe network.

Los Angeles. Due to its large size (4") and high water use, it was not possible to disaggregate water use at this site beyond the indoor use category. Total indoor demand, which included both cooling water and domestic indoor, was estimated at 26,482 gpd across an entire seven-day week. Cooling water usage accounted for 15,360 gpd (58 percent) of the total indoor usage and domestic indoor (toilets, faucets, cleaning, etc.) accounted for 11,122 gpd (42 percent) of the total. The measured average daily indoor usage during the logging period (two business days and two weekend days) days was 19,602 gpd.

The primary outdoor water use at the site was the irrigation of 4,000 sf of landscape. The total outdoor use during the logging period was 6,740 gallons. The average irrigation application rate for landscape during the logged period was 1,685 gpd or 0.42 gallons per square foot (gpsf) of landscape. Based on 250 watering days per year, the estimated annual irrigation demand at the site is 420 kgal. On an annual basis this implies that the total irrigation rate was approximately 105 gallons or 168 inches (14 feet) of application per square foot. However, it is not known if the irrigation measured during the logging period is representative of irrigation use throughout the year.

During the logging period a continuous demand in the form of cooling water and possibly leakage was observed in the flow trace. The cooling system at the building included an open looped 425-ton evaporative cooler and a closed loop 90-ton cooler. The estimated summer peak cooling water load, based on 75 percent of the cooling capacity, is approximately 20,200 gpd. The measured average business day cooling water usage during the logging period was 13,500 gpd. The average daily indoor demand (uses other than cooling) based on a 7 day week was 13,275 gpd. Winter cooling water usage was estimated at 25 percent of cooling tower capacity or approximately 6,000 gpd.

Phoenix. This site had a 2-inch water meter that provided good resolution to the data logger and made it possible to disaggregate and identify the majority of the indoor uses at the site. Toilet flushes constituted the majority of all indoor water use. The other large observed indoor water uses were for faucets and a dishwasher.

The majority of water used at this clinic office building during the logging period was for outdoor purposes. This building was equipped with a single water meter, so to get an accurate determination of the annual outdoor water usage it was necessary to extrapolate monthly indoor use from the logging data and then subtract annual indoor demand from total annual use. This approach for estimating outdoor demand has proven accurate because indoor use generally does not fluctuate with the seasons like outdoor use. The office building is located in a region where irrigation can occur during all months of the year so that minimum month techniques tend to underestimate irrigation demands.

During the logging period there was no continuous demand in the office building. The building used no water for cooling and did not have any continuous leakage.

San Diego. This site had a 1.5-inch water meter that provided good resolution to the data logger and made it possible to disaggregate and identify the majority of the indoor uses at the site. Toilet flushes constituted the majority of all indoor water use. Other observed indoor water use included faucets, showers, leakage and other miscellaneous demands. The miscellaneous indoor usage appeared to be primarily toilet flushes and faucet use that could not be disaggregated into discrete events.

Outdoor use represented a small percentage of total water use at this site. The total irrigated area at the site is less than 100 sf. The annual irrigation rate was estimated at 20 gpsf per year or 32 inches of water per square foot of landscape.

During the logging period there was a small amount of continuous leakage at the site. The total leakage during the logging period was 116 gallons. The average daily leakage during the logging period was 58 gpd or 2.5 gallons per hour (gph).

Santa Monica. This building was unique among those studied in the degree to which systems were monitored and controlled by the facilities manager. It was the only building in which all of the fixtures and appliances had been updated with high efficiency devices. It also was the only building in which the cooling tower was equipped with sand filtration, pH and disinfecting controls, and meters on the bleed-off lines. A water sampling laboratory had been constructed in a room adjacent to the air conditioning equipment. At this location samples were taken from all of the cooling tower flow streams for chemical analysis and control. As a result, the indoor usage per square foot at this building was the lowest of all five buildings, and its cooling use was approximately one third of that in the other buildings in the study equipped cooling towers.

Because of the size of this building, the large amount of daytime cooling water use, and the fact it had a 4" meter which provides relatively poor resolution of low volume, short duration water use events, it was not possible to identify all of the individual indoor water use events. The logged average daily indoor use was 8250 gpd. By far the largest indoor use was the building's cooling demand. The summer cooling water accounted for 6200 gpd and 75 percent of all indoor water use. Toilets, urinals, faucets, showers and dishwashers used an average of 2050 gpd. Based on the logging results it was estimated that there were approximately 60 toilet/urinal flushes an hour during the 10 hours per day that the building was occupied. The estimated average daily toilet/urinal usage was 1350 gpd. The 700 gpd of the other domestic indoor usage was composed mostly of faucet usage.

The primary outdoor water use at the site was the irrigation of 5000 square feet of immaculately tended landscape. The average irrigation application rate for the landscape during the logged period was 1660 gpd or 0.33 gallons of water per square feet. The annual irrigation rate was estimated to be 181 gpsf or 290 inches (24 feet) of irrigation application per year.

However, it is not known if the irrigation measured during the logging period is representative of irrigation use throughout the year. The building also had a 1000 square foot fountain that used 400 gpd to fill and clean.

The flow trace data showed a continuous demand of 1.5 gpm apparently from a combination of the 200-ton closed loop cooling tower and whatever leakage was present in the building. This cooling tower operated continuously. In addition, there was a larger continuous demand (5.5 gpm) during the daytime business hours from the two open loop cooling towers that are operated 10 hours per day.

Average daily demand during the logging period was 80 percent of the average annual use rate. Correcting for this difference, the annual make-up water for the cooling towers was estimated at 2.25 million gallons. This cooling demand estimate was confirmed using a theoretical calculation based on the metered bleed off rate, the measured concentration ratio, and average capacity use estimates.

Estimated Annual End Uses

The estimated annual end uses for each office building are shown in Table 4.4. Estimates of demand in individual use categories are shown for sites where it was possible to disaggregate demand from the logging data. The idea of using engineering estimates or event data from one building to disaggregate demand in another was rejected because the goal of the direct measurement field studies was to base end use demand on direct measurements rather than on inferences or induction.

It is difficult to use the results shown in Table 4.4 to compare demand between office buildings because the range in building size is so great. To properly compare between sites, the data were normalized on the basis of use per square foot of floor space (for indoor uses) and irrigated area (for outdoor uses). The normalized end use results are presented in Table 4.5.

Table 4.4 Estimated annual end uses of water in field study office buildings (kgal/year)

	Irvine	Los Angeles	Phoenix	San Diego	Santa Monica
Demand (kgal/year)					
Indoor					
Faucets	32		49.7	46.5	
Ice machines	0		0.0		
General indoor	0		0.0		
Other/misc. uses	215		2.0	63.5	255
Shower	0		0.0		
Toilet	315		83.3	242	500
Total Indoor	562	4,035	135	352	755
Continuous					
Cooling	0	6,000	0	0	2,250
Other continuous (leaks, etc.)	0	0	0	20	0
Total indoor + continuous	562	10,035	135	350	3,005
Outdoor Use					
Outdoor	1,477	420	273	2	800
Fountain	0	0	0	0	100

Table 4.5 Normalized end uses in field study office buildings (gal/sf/yr)

	Irvine	Los Angeles	Phoenix	San Diego	Santa Monica
Demand (gal/sf/year)					
Indoor*					
Faucets	0.55		4.97	5.30	
Ice machines	0.00				
General indoor	0.00				
Other/misc. uses	3.72		0.19	7.22	1.37
Shower	0.00				
Toilet	5.45		8.33	27.50	2.70
Total Indoor	9.72	22.86	13.49	40	4.07
Continuous*					
Cooling	0.00	34.00	0.00	0.00	12.10
Other continuous (leaks, etc.)	0.00	0.00	0.00	2.27	0.00
Total indoor + continuous	9.72	56.86	13.49	39.77	16.17
Outdoor Use					
Outdoor†	63.00	105.00	113.75	20.0	160.00
Fountain‡	0.00		0.00	0.00	100.00

*Based on square footage of office space

†Based on irrigated area

‡Based on square footage of fountain

To permit the results from the direct measurement field studies to be correlated with the conditional demand models, information has been extracted for values of the model variables where available from the field studies. Only those variables for which positive, non-zero, data exist were tabulated. Variables that exist at the sites, but have unknown values, have been listed as unknown. The modeling parameters are presented in Table 4.6.

Table 4.6 Model parameters from field study office buildings

Model Parameter	**Irvine**	**Los Angeles**	**Phoenix**	**San Diego**	**Santa Monica**
Kitchenettes	2	12	2	2	11
Kitchens	0	0	0.	0	0
Display fountains	0	1	0	0	1
Dishwashers	1	0	1	0	6
Laboratories	0	0	1	0	0
Public Restrooms	9	12	7	6	22
Tank Toilets	0	0	7	0	0
Valve Toilets	24	50	0	15	64
Public Urinals	4	15	0	6	15
Sanitary Faucets	9	44	7	12	67
ULF Toilets	0	0	0	0	64
Showers	0	0	0	2	0
Wash Stations	4	6	2	3	11
Cooling Towers	0	1 open loop 1 closed loop	0	0	2 open loop 1 closed loop
Cooling Tons	0	428 open loop 90 closed loop	0	0	360open loop 200closed loop
Chillers	1	1	1	1	1
Chiller Capacity	unknown	unknown	Unknown	unknown	unknown
Ice Machines	0	1	0	0	1
Feed Water TDS	NA	290	NA	NA	600
Concentration Ratio	NA	3.8	NA	NA	3.3

Restaurants

General Information

Five restaurants were visited during the course of the fieldwork. All of these were family style, sit down establishments as opposed to fine dining or fast food restaurants. All five restaurants had table service and on-site dish washing. The restaurants ranged in size from 73 to 253 seats and served from 190 to 800 meals per day. None had evaporative cooling towers, although there were two swamp coolers in Phoenix that were used regularly. Three out of five had no irrigation. The Los Angeles site had 250 sf of planters and the Phoenix site had a sizeable amount of turf to irrigate. Table 4.7 shows fundamental information about each establishment.

Table 4.7 General information on field study restaurants

	Irvine	Los Angeles	Phoenix	San Diego	Santa Monica
Meter size	1 ½	1½	1 ½	1	1 ½
Flow trace resolution	high	med	med	high	med
Avg. meals served/day	750	800	700	190	540
Number of seats	253	200	149	216	73
Number of employees	50	100	50		25
Building area (sf)	4,500	9,800	4,825		1,200
Irrigated area (sf)	0	250	11,750	0	0

Annual and Seasonal Use

Table 4.8 shows the annual and seasonal use at the five restaurants. The annual use for the restaurants visited ranged from a low of 734 kgal in Irvine, to 3,528 kgal in Phoenix. The equivalent average daily use ranged from just over 2 to 9.67 kgal per day. It is not surprising to note that the only restaurants with a significant seasonal component to their water use—as defined using their average winter consumption—were the two where irrigation was being conducted.

Table 4.8 Annual and seasonal use in field study restaurants (kgal)

	Irvine	Los Angeles	Phoenix	San Diego	Santa Monica
Total annual use (kgal)	734	3,252	3,528	1,319	785
Average daily use (kgal)	2.01	8.91	9.67	3.61	2.15
Non-seasonal (kgal)	734	2,774	2,434	1,319	785
Seasonal (kgal)	0	479	1,094	0	0

Logging Data

Flow traces were obtained at each restaurant during the summer of 1998. Table 4.9 shows the water use patterns during the logging. As was the case with office buildings, the only site that varied significantly from its billed average daily usage was the San Diego site. This restaurant had a large continuous leak during the logging period.

Table 4.9 Water use patterns at field study restaurants during logging periods

	Irvine	Los Angeles	Phoenix	San Diego	Santa Monica
Logged average daily use (kgal)	2.3	9.7	7.3	7.2	1.5
Billed average daily use (kgal)	2.0	8.9	9.7	3.6	2.2
Indoor peak instantaneous demand (gpm)	36.0	59.6	39.6	27.0	21.1
Outdoor peak instantaneous demand (gpm)	N/A	41.0	89.8	N/A	N/A
Length of flow trace (days)	9.9	6.1	2.7	2.5	7.8

Disaggregation of Flow Trace Data

A brief description of the results from the flow trace analysis of water use at each restaurant is provided below. Each site is discussed with respect to the level of disaggregation achieved by the flow trace analysis in indoor, outdoor and continuous uses.

Irvine. The indoor demand measured at the Irvine site consisted of uses for sanitary, food preparation, and general cleaning purposes. The average daily water use at this site is approximately 2,300 gpd. It was possible to disaggregate the flow trace obtained over the 9 day logging period into the following end uses: clothes washers, dishwashers, faucets, ice making, and toilet/urinals.

The only outdoor demand associated with this site was for patio and sidewalk washing. It was not possible to distinguish this use from the other miscellaneous faucet use at the site and hence was included in that category. According to the manager, the sidewalk washing activity takes place approximately once per week.

There was no continuous use measured at the site. Each night the flow fell to zero for several hours, interrupted only occasionally by flow for the ice machines.

Los Angeles. The indoor demand present at this site consisted of uses for sanitary, food preparation, general cleaning purposes. The average daily indoor water use at this site during the logging period was approximately 9,352 gpd. It was not possible to disaggregate the flow trace obtained during the 6.1 days of logging into individual end-uses.

The Los Angeles restaurant site had an automatic sprinkler system that irrigated approximately 250 square feet of bushes and shrubs. The irrigation system was equipped with a sprinkler clock, but at the time of the water audit the irrigation controller was being operated manually.

This site had a small continuous flow from leakage occurring within the restaurant. This flow was fairly constant at 0.25 gallons per minute or 360 gpd

Santa Monica. This restaurant was small and had a high resolution water meter which permitted accurate disaggregation of interior water use. The indoor demand at this site consisted of water used for food preparation, general cleaning purposes, toilet flushing, and bathroom faucets. The average daily indoor water use at this site (including leaks) during the logging was approximately 2,105 gpd. That largest daily use was faucets (815 gpd) followed by dishwashers (615 gpd).

There was a single measurable outdoor water use event during the data logging period. This event occurred during the daytime and was most likely associated with miscellaneous hose usage associated with heavy cleaning, watering small plant beds, or washing down pavements. The total outdoor usage during the logging period was 440 gallons or 57 gpd.

This site had a constant, regular leak. The nighttime hourly demand (after the restaurant was closed) rarely dropped below 1 gph, and the average nighttime demand was 8.5 gph. There was no indication that this leak stopped during the day, so a continuous leakage of rate was projected for all periods of water use except for periods when minimum usage dropped below 8.5 gph.

San Diego. The indoor demand at this site consisted of uses for sanitary, food preparation, and general cleaning purposes. The average daily indoor water use at this site during the logging period (excluding continuous leakage) was 3,050 gpd. Due to the high rate of leakage during the data collection period it was not possible to disaggregate indoor demand into individual end uses.

There was no outdoor use at this site.

This site had continuous leakage occurring in all but 6 hours of the 2.5 day logging period. From the field audit the two main causes for this leakage were known. The restaurant had a toilet with a flapper valve that required manual resetting each time the toilet was flushed and there was a kitchen faucet that would not shut off. The flow from the toilet flapper leak was approximately 4 gpm and the flow from the faucet leak was approximately 1.5 gpm.

Phoenix. The indoor demand at this site consisted of uses for sanitary, food preparation, and general cleaning purposes. The average daily indoor water use at this site during the logging period (excluding continuous use from the evaporative coolers) was a 2,160 gpd. It was possible to disaggregate the flow trace obtained during the 2.66 days of logging into the end uses.

The restaurant had an automatic sprinkler system that irrigates approximately 11,750 square feet of turf and trees. The system is equipped with an irrigation clock, but at the time of site visit the irrigation controller was broken the system was operated manually.

This site had a continuous flow from the restaurant's twin 8300 cfm evaporative coolers. The continuous flow varied between 1 and 2 gallons per minute depending upon the diurnal cooling load at the restaurant. During the logging period there was little daily variation in the cooling water usage at the restaurant. The average cooling water usage was 1,973 gpd with a maximum of 1,991 gpd and a minimum of 1,956 gpd.

As a group, demand in restaurants was relatively easy to disaggregate into component end uses. In three out of the five establishments it proved possible to identify the main indoor uses from the flow trace data. In both the sites that proved impossible to disaggregate, large leaks occurred which obscured the detail. Table 4.10 shows the annual end uses at each restaurant by volume, and Table 4.11 shows the end uses normalized according to the average number of meals served per day. Table 4.12 shows water use normalized on the basis of gallons per seat per year.

Table 4.10 Average annual end uses in field study restaurants (kgal/yr)

Demand (kgal/yr)	Irvine	Los Angeles	Phoenix	San Diego	Santa Monica
Indoor					
Faucets	310		680		300
Dishwashing	245		350		220
Toilets/Urinals	115		145		90
Ice Making	35		215		45
Clothes Washing	30		0		0
Other/Misc. Indoor	0		0		21
Total indoor	735	3,070	1,390	1,120	676
Continuous					
Leaks	0	130	0	200	76
Cooling	0	0	730		0
Outdoor					
Irrigation	0	55	1,410		0
Other/Misc. Outdoor	0	0	0		33
Total	735	3,255	3,530	1,320	785

Table 4.11 Restaurant use normalized on the average number of meals served per day (gal/meal)

Demand (gallons/meal served)	Irvine	Los Angeles	Phoenix	San Diego	Santa Monica
Indoor					
Faucets	1.1		2.6		1.5
Dishwashing	0.9		1.4		1.1
Toilets/Urinals	0.4		0.5		0.5
Ice Making	0.1		0.9		0.2
Clothes Washing	0.1				0.0
Other/Misc. Indoor	0.0				0.1
Total indoor	2.7	10.5	5.4	16.2	3.4
Continuous					
Leaks	0.0	0.5		2.9	0.4
Cooling	0.0	0.0	2.9	0.0	0.0
Outdoor					
Irrigation	0.0	0.2	5.5	0.0	0.0
Other/Misc. Outdoor	0.0	0.0	0.0	0.0	0.1
Total	2.7	11.1	13.8	19.1	3.9

Table 4.12 Restaurant use normalized on the number of seats (gal/seat/yr)

Demand (gallons/seat/year)	Irvine	Los Angeles	Phoenix	San Diego	Santa Monica
Indoor					
Faucets	1,225		4,630		4,100
Dishwashing	970		2,350		3,000
Toilets/Urinals	455		975		1,230
Ice Making	140		1,440		610
Clothes Washing	120		0		0
Other/Misc. Indoor	0		0		285
Total indoor	2,910	15,350	9,395	5,185	9,225
Continuous					
Leaks	0	660	0	925	1,050
Cooling	0	0	4,900	0	0
Outdoor					
Irrigation	0	275	9,450	0	0
Other/Misc. Outdoor	0		0		450
Total	2,910	16,285	23,745	6,110	10,725

Modeling Parameters

In order to relate the results of the direct measurement field studies to the CDA model, the data on modeling parameters for each site are shown in Table 4.13.

Table 4.13 Modeling parameters for restaurants

Model Parameter	**Irvine**	**Los Angeles**	**Phoenix**	**San Diego**	**Santa Monica**
Public/employee restrooms	2	4	2	2	3
Tank toilets	0	0	0	0	2
Valve toilets	3	5	4	3	2
Urinals	2	2	2	1	2
Faucets	3	4	4	2	3
ULF toilets		5			
Drinking fountains	1	1	1	1	1
Landscape irrigation (sf)	0	250	11,750	0	0
Pavement washing	1/wk	0	0	1/wk	0
Leak	>0.5 gph	15 gph	1 gph	8.5 gph	210 gph
Fountain	0	0	0	0	0
Water treatment	1 non cons.	1	1	1	1
Cooling tower	0	0	0	0	0
Evaporative condensers	0	0	0	0	0
Swamp cooler (cfm)	0	0	2@8300	0	0
Hot water boilers	1	0	1	0	0
Bar	0	1	1	0	1
Bar faucets	0	2	3	0	3
Auto dishwashers	1	1	1	1	1
Scullery nozzles	1	1	1	1	!
Garbage disposals	1	1	0	1	1
Garbage strainer	0		Manual		1
Ice machine	1	3	1	1	1
Dishwashing sink			3	1	2
Floor hose	1	1	1	1	1
Utensil bins			4		
Pot sink	1	1	1	1	1
Food prep sinks	6	7	2	1	4
Hand wash sinks			3	1	4
Hand washer	1	1	1	1	1

Supermarkets

General Information

The five supermarkets studied for the direct measurement field studies were large, full service stores with all of the departments one would expect to find in a modern, urban food store including: produce, meat, deli, and bakery department. Each supermarket had some form of hot food service ranging from Chinese grills to Mexican and Italian specialty foods. Without exception, however, the single largest water consuming device in each store was the cooling tower that provided cooling for air conditioning, refrigeration, freezers, and chillers. Table 4.14 provides general information about the five supermarket sites.

Table 4.14 General information about field study supermarkets

	Irvine	**Los Angeles**	**Phoenix**	**San Diego**	**Santa Monica**
Meter size (inches)	2	1 ½	2	2	2
Flow trace resolution	med	high	med	med	med
Avg. transactions/day	3,900	3,300	2,550	3,150	3,300
Building size (sf)	38,000	50,000	48,000	66,000	45,000
Irrigated area (sf)	0	0	10,640	0	54,000
Evaporative cooling tons	200	200	200	260	240
Tap water TDS	220	140	700	400	300
Cooling concentration ratio	2.7	1.9	2.2	2.2	3.3

Annual and Seasonal Use

Table 4.15 shows the annual and seasonal use for the supermarkets. Non-seasonal use varied from a low of 1.9 million gallons to a high of 5.1 million gallons. The only stores which showed significant seasonality in their use were those which had irrigation. This suggests that the summer increase in air conditioning load was not as great as the normal use for food storage refrigeration. The total annual use for these five stores was between 3.8 and 5.1 million gallons, and the average daily use ranged from 10.6 to 13.9 kgal.

Table 4.15 Annual and seasonal use in field study supermarkets (kgal)

	Irvine	Los Angeles	Phoenix	San Diego	Santa Monica
Total annual use (kgal)	3,934	5,072	4,156	3,877	4,311
Average daily use (kgal)	10.78	13.90	11.40	10.62	11.81
Non-seasonal (kgal)	3,934	5,072	1,943	3,877	3,689
Seasonal (kgal)	0	0	2,213	0	622

Logging Data

Flow trace data were successfully obtained at each of the five sites. Table 4.16 shows the water use patterns at the five stores during the logging. The daily use during the logging was reasonably similar to the annual use patterns, ranging from 9.7 to 14.3 kgal. The peak instantaneous indoor demands at the stores ranged from 30 to 60 gpm, which could be served by a 1 ½" meter.

Table 4.16 Water use patterns at field study supermarkets during logging periods

	Irvine	Los Angeles	Phoenix	San Diego	Santa Monica
Average daily use (kgal)	12.28	14.33	9.71	12.80	12.58
Indoor peak instantaneous demand (gpm)	54.40	58.79	42.03	29.70	44.20
Outdoor peak instantaneous demand (gpm)	0	0	38	0	76.5
Length of flow trace (days)	9.81	7.79	2.66	2.49	6.81

Disaggregation of Flow Trace Data

Irvine. It was virtually impossible to identify individual indoor water use events on a consistent basis from the single flow trace recorded at this site. From the site visit it is known that the following water uses were present in this supermarket:

- Sanitary uses for toilets, urinals, and hand sinks.
- Filling of three compartment sinks for washing vegetables, pots and pans in the various food preparation areas.
- Food preparation sinks in the deli and bakery, including water used for washing and combining ingredients.

- Spraying vegetables in produce racks.
- Washing floors, counters and walls in food preparation areas.

It was not possible to disaggregate demand into individual uses in this flow trace. Estimates based on assumed use parameters were thought mere guesswork, so the indoor use was left mainly in a disaggregated form. The one exception was toilet and urinal flushing. It was possible to count the number of flush events that occurred on an average day (212 fpd) and multiply this by the average flush volume of 3.5 gallons to arrive at an estimate of 742 gpd of toilet water.

The only continuous use at this store was the cooling water demand, which averaged 5 gpm or 7,200 gpd. This continuous demand could mask leakage. During the logging period, the continuous cooling demand accounted for approximately 60 percent of all water use at the supermarket.

Los Angeles. It was impossible to disaggregate water use in the store beyond the level of general indoor use with the exception of toilet and urinal flushing, which could be identified enough of the time to allow for a reasonable estimate of use in that category.

There was no outdoor use at this site, and the only continuous use at this store was the cooling water demand, which averaged 7 gpm or 9,575 gpd. During the logging period cooling demand accounted for approximately 68 percent of all water use.

Santa Monica. The only specific indoor end uses that could be identified from the flow trace were toilet and urinal flushing. It was usually possible to count the number of flush events per day, which averaged 250 fpd with an average volume of 3.5 gpf. An estimated 875 gpd was used for flushing toilets and urinals.

The primary outdoor water uses at this site was irrigation of the store's 54,000 square feet of landscape and the outdoor fountain in front of the store. The total outdoor use during the 6.8 day logged period was 13,130 gallons. The average irrigation application rate for landscape during the logged period was 2,190 gpd. From the estimated annual outdoor water usage of 751,000 gallons, the total irrigation rate was 14 gallons or 22.5 inches of application per square foot per year, which is considerably less than the theoretical ET irrigation requirement of 31 inches.

The only continuous use at this store was the cooling water demand from the 240-ton evaporative condenser. The average water demand for this device was 4.5 gpm or 6,450 gpd. During the logging period this accounted for approximately 52 percent of all water use.

San Diego. There were a large number of small faucets and miscellaneous uses that could not be disaggregated, but it was possible to occasionally identify toilet and urinal flush valves due to their unique flow patterns. It was estimated that there was an average of 150 fpd at this store at a volume of 3.5 gpf.

The only continuous use at this store was the cooling water demand, which averaged 5 gpm or 7,200 gpd for the entire logging period. Cooling water use accounted for approximately 65 percent of all water use during the logging period.

Phoenix. Two thirds of all indoor demand was used for cooling at this site. Flush valves were the only end use that could be disaggregated. The primary outdoor water use was the irrigation of the buildings 10,650 square feet of landscape. The total outdoor use during the logging period was 820 gallons. The average irrigation application rate for the landscape during the logged period was 410 gpd or 0.04 gpsf. At this rate the annual irrigation rate would be approximately 27 gallons or 43 inches of application per square foot.

Estimated End Uses in Supermarkets

Table 4.17 shows the estimated annual water use according to the identified end uses at the field study supermarkets, and Table 4.18 shows the uses normalized on the basis of square feet of store area. In all five supermarkets studied, cooling use constitutes the largest category and generally accounts for twice the total of all other indoor uses combined. Water use for irrigation appears to be a function of a number of variables including the irrigated area, climate etc. Outdoor use at the two sites with irrigation represented of 12 percent of total demand at the supermarket.

Table 4.17 Estimated annual end uses in field study supermarkets (kgal/yr)

	Irvine	Los Angeles	Phoenix	San Diego	Santa Monica
Demand (kgal/year)					
Indoor					
Misc. faucets					
Toilets/urinals	270	280	320	190	320
Other/misc. indoor	1,261	1,405	895	1,125	1,050
Total indoor	1,531	1,685	1,215	1,315	1,370
Continuous					
Cooling	2,234	3,390	2,655	2,560	2,190
Leaks					
Outdoor					
Irrigation	0		286		751
Other/misc. outdoor	0				
Total	3,765	5,075	4,156	3,875	4,311

Table 4.18 Normalized end use at field study supermarkets (gal/sf/yr)

	Irvine	Los Angeles	Phoenix	San Diego	Santa Monica
Demand (gal/sf/year)					
Indoor*					
Toilets/urinals	270	280	320	190	320
Other/misc. indoor	1,261	1,405	895	1,125	1,050
Total indoor	1,531	1,685	1,215	1,315	1,370
Continuous*					
Cooling	58.8	67.8	55.3	38.0	48.7
Leaks					
Outdoor†					
Irrigation			27.0		14.0
Other/Misc. Outdoor					
Total	99.1	101.5	107.6	58.0	79.1

* Normalized on building area (sf)
† Normalized on irrigated area (sf)

Table 4.19 Modeling parameters for field study supermarkets

Model Parameter	Irvine	Los Angeles	Phoenix	San Diego	Santa Monica
Public/employee restrooms	2	2	3	4	4
Tank toilets	0	0	0	0	0
Valve toilets	3	3	4	7	4
Urinals	1	3	2	2	1
Faucets	4	3	3	4	4
ULF		3		2Toilets	
Drinking fountains	1	1	1	1	1
Sinks in store:					
Bakery	1	1	1	1	1
Meat department	1	1	1	1	1
Dairy	1	1	1	1	1
Produce	1	1	1	1	1
Seafood		1		1	
Live fish aquarium	1			1	
Floral				1	1
Deli			1	1	
Juice bar					
Restaurant		1			1
Water treatment			1 non cons		1
Ice machine	4	3		2	2
Produce mist sprayer	1	1	1	1	1
Produce grinder	1	1		1	
Irrigation	0	0	10,640	0	54,000
Cooling tower	1-200	1-200	1-200	1-240	2-260
Decorative fountain				1	
Restaurant		1			1
Salad bar	1			1	1
Dishwashers	0		3	3	
Utility sink	1	1	1	1	1
Department sinks	12	4	5	7	11
Floor hose	1	1	1	1	1
Scullery nozzles					1
Disposals					
Produce sink	1	1	1	1	1
Pot sink		1			1
Food prep sinks	1			1	2
Hand wash sinks	1	1	1	1	3
Bottled water machine		1			
Wok table faucet		1			3

Modeling Parameters

Table 4.19 provides information available on the CDA modeling parameters for the supermarkets.

Hotels

General Information

Water use in five hotels was examined as part of the direct measurement field studies. General information about each of the five hotels is presented in Table 4.20. Three of the hotels were economy/budget franchises. The Santa Monica site was a combination economy travel lodge and beach resort. The Los Angeles site was near Beverly Hills and was a large luxury class hotel with a full restaurant and banquet facility that was clearly outside the parameters established for this study in terms of size, price range, and on-site facilities. It was an example of inclusion based primarily on willingness to participate discussed previously.

Table 4.20 General information on field study hotels

	Irvine	Los Angeles	Phoenix	San Diego	Santa Monica
Meter Size	2 @ 2"	6"	3 @ 2"	2 @ 2"	4"
Flow trace resolution	med	low	Med	med	low
Number of rooms	148	297	140	209	168
Occupancy rate (peak season)	90%	74%	90%	100%	85%
Occupancy rate (off season)	90%	74%	60%	80%	85%
Avg. guests/room	2	1.2	1.3	2	3
Restaurant	0	1	0	0	0
Banquet facility	0	1	0	0	0
Irrigated area (sf)	0	31,743	22,672	0	5,510
Cooling tons	0	600	0	0	200
Clothes washers	4	2	3	3	6
Hours of laundry use	8	4	8.5	10	8
Pool (sf)	800	375	800	225	320

Annual and Seasonal Use

The annual and seasonal use in the five field study hotels is shown in Table 4.21. With the exception of the Los Angeles site, annual demand in the group was relatively consistent, typically between 6 and 9 million gallons per year. The Los Angeles site, however, used over 19 million gallons, much of this related to operation of its cooling towers. The seasonal component of water use at the five hotels was primarily due to increased irrigation, pool use and cooling.

Table 4.21 Annual and seasonal demand at the field study hotels (kgal)

Demand (kgal)	Irvine	Los Angeles	Phoenix	San Diego	Santa Monica
Total annual use	5,887	19,499	9,245	7,503	8,657
Average Daily Use	16.1	53.4	25.3	20.6	23.7
Non-seasonal (AWC)	5,269	16,184	7,140	6,952	6,597
Seasonal (AWC)	618	3,315	2,105	551	2,060

Logging Data

Table 4.22 shows the measured water use in the field study hotels during the logging periods. Daily water use during the logging period was quite similar to the annual daily water use calculated from the billing data. Peak instantaneous demands for indoor uses at the hotels ranged from 41 to 130 gpm. Peak instantaneous outdoor demands ranged from 32 to 150 gpm.

Table 4.22 Water use patterns at field study hotels during logging periods

	Irvine	Los Angeles	Phoenix	San Diego	Santa Monica
Demand					
Logged average daily use (kgal)	18.8	59.3	29.3	23.6	18.6
Billed average daily use (kgal)	16.1	53.4	25.3	20.6	23.7
Indoor peak instantaneous demand (gpm)	106.9	130.7	83.7	69.9	40.5
Outdoor peak instantaneous demand (gpm)	85	149.4	141.8	0	31.7
Length of flow trace (days)	9.8	2.9	2.8	2.5	6.8

Disaggregation of Flow Trace Data

Irvine. Indoor water use at the Irvine site was disaggregated into several categories. Each indoor water use had its own characteristic flow pattern, timing, and duration. Many of these uses were identified from examination of the flow traces recorded from the 2" meters. However, some indoor uses were too small and had too short a duration to be distinguished at the desired level of resolution.

At Irvine additional details on in-room uses were obtained by sub-metering. During the initial site visit it was learned that groups of 9 to 12 rooms were supplied through separate hot and cold riser lines which came off of main lines in the attic, precisely the situation which was hoped for. In November of 1998, two standard ¾ inch water meters were installed on one set of feed lines that supplied a group of nine rooms. Flow traces were obtained from the water meters on both the hot and cold water risers and then disaggregated into end uses. The loggers were left in place for a full 7-day period. The hotel manager then provided room occupancy information on the nine sub-metered rooms for the period that the loggers were in place. The resulting data sets provided detailed information on per room and per capita hot and cold water use for toilets, showers, baths, faucets and leaks.

A breakdown of the indoor use is provided in Table 4.23. During the 7 days over which flow trace data were obtained, these nine rooms used a total of 3,797 gallons of water or 60 gallons per room per day for all in-room uses. Of the total, 2,257 gallons or 59 percent was cold water and 1,540 gallons or 41 percent was hot water.

The largest single end use in these rooms was showers, followed by toilets. The hotel guests used 28 gallon per day for showers, which was 47% of the in-room use. Toilet use accounted for 26 gallons per day, or 42 percent of in-room use. Together, these two categories made up 89 percent of in room use. Faucet use accounted for 9 percent of the in-room use and leaks made up only 2 percent.

The flow traces provided information about the efficiency of the in-room fixtures. The shower flow rates, for combined hot and cold water, ranged considerably from 2.5 gpm to over 5 gpm. This implies that not all of the showers in the hotel meet the current low flow rating. During the 7 logged days, a total 352 flushes were counted, resulting in a per flush volume of 4.4 gpf. This result indicates that the per room use of 60 gpd could be reduced through the installation of ULF toilets and additional attention to insure that LF showerheads are present in each room.

Table 4.23 Disaggregated indoor use at Irvine hotel

End Use	Total Logged Use				Daily Use		Hot/Cold	
	Cold (gal)	Hot (gal)	Total (gal)	%	Total (gal)	Per Room (gal)	Cold %	Hot %
Faucet	125	233	358	9%	51	6	35%	65%
Leak	10	41	50	2%	7	1	20%	80%
Shower	515	1,266	1,781	47%	255	28	29%	71%
Toilet	1,607	0	1,607	42%	230	26	100%	0%
Total	2,257	1,540	3,797	100%	543	60	59%	41%

Based on 7 day logging period

The largest component of the water use at this hotel was for indoor purposes. There was measurable outdoor use for backwashing the swimming pool and hot tub filters, incidental planter irrigation, and washing of walks and pavements. The average daily use identified as "outdoor" amounted to 849 gpd. The average daily use for indoor purposes and leaks was estimated to be 18,000 gpd.

This hotel has no true continuous uses in terms of process water such as cooling or treatment, or continuous leakage. There were several times during the logging period where large continuous use events occurred which appear to be leakage, probably due to toilets with stuck flapper valves.

Los Angeles. It was not possible to install sub-meters at the Los Angeles site, and the flow traces did not provide enough resolution for individual water uses to be disaggregated. It was possible to separate out irrigation and continuous (cooling and leakage) from all other hotel water use. Using the annual billing and the seasonal use calculation, annual estimates of daily water use on a per room basis were developed. Sub-metered data from the two sub-metered sites were used to estimate in-room end uses for the Los Angeles site.

Outdoor use at the Los Angeles site was disaggregated from the flow traces because the pattern of automatic irrigation could easily be distinguished. The irrigation system was operated in the morning every day the loggers were in place. The daily outdoor irrigation use during the logging period was estimated at 6,657 gpd. During the logging period, irrigation accounted for 11 percent of the total water use.

This hotel had significant continuous water use for cooling, treatment, and probably leakage. The observed flow patterns are typical of large tower evaporative cooling demand and the flow trace revealed an increased continuous flow during the daylight hours when the demand for cooling was greater.

Santa Monica. Indoor demand at the Santa Monica site could not be directly disaggregated, and it proved impossible to install sub-meters at this site. Consequently, estimates were developed for in-room, laundry, other miscellaneous indoor uses, and for the swimming pool and hot tub.

Outdoor use at the Santa Monica site was disaggregated from the flow traces because the sprinkler system was operated early in the morning every day the loggers were in place and the pattern easily distinguished. The daily outdoor irrigation use during the logging period was measured to be 577 gpd. There was additional irrigation use associated with flowerbeds and houseplants that are not part of the automatic irrigation system. Ultimately it was estimated that outdoor irrigation represented 3 percent of the total water use measured at the Santa Monica site during the logging period. This hotel also had a large 550-ton cooling tower that accounted for a continuous water demand.

San Diego. The San Diego site has two buildings: a new four-story tower, and an older building. The four-story tower was the focus of this study. Water use at this site included in-room domestic, ice machines, laundry, and miscellaneous domestic uses such as cleaning and washing. There was no evaporative cooling, swimming pool or irrigation.

It was not possible to install sub-meters at this hotel, but average per room per day consumption at the Motel 6 was quite similar to consumption at the La Quinta Inn, Irvine that was sub-metered. Average per room consumption at the Motel 6 was 110 gallons per occupied room per day while at La Quinta consumption averaged 109 gpd/room.

Phoenix. The La Quinta, Phoenix was the second hotel to be sub-metered. At this hotel, sub-meters were installed on the hot and cold water lines serving four rooms, and two weeks of data flow trace data were obtained simultaneously from both sub-meters during peak season of March 1999. The hotel managers provided occupancy data covering the two week logging period for the four monitored rooms. The results of this sub-metering effort include detailed information on in-room per capita use. This information in conjunction with the initial flow trace and billing data allowed for detailed disaggregation of indoor use. These data were used along with the results from the Irvine site to make estimates of in-room use in the other hotels studied.

A breakdown of the indoor use is provided in Table 4.24. During the 14.75 days over which flow trace data were obtained, guests in these four rooms used a total of 5,088 gallons of water or 86.2 gallons per room per day for all in-room uses. Of the total, 3,455 gallons or 68 percent was cold water and 1,623 gallons or 32 percent was hot water.

The largest single end use in these rooms was showers, followed by toilets. The rooms used 37.6 gallon per day for showers, which was 44% of the in-room use. Toilet use accounted for 32.5 gallons per day, or 38 percent of in-room use. Together, these two categories made up 82 percent of in room use. Faucet use accounted for 8 percent of the in-room use, leaks made up 7 percent and bathtub usage made up only 3 percent.

Table 4.24 Disaggregated indoor use at Phoenix hotel

End Use	**Total Logged Use**				**Daily Use**			**Hot/Cold**	
	Cold (gal)	**Hot** (gal)	**Total** (gal)	**%**	**Total** (gal)	**Per Room** (gal)	**Per Person** (gal)	**Cold** %	**Hot** %
Bathtub	57	100	157	3%	11	2.7	2.0	6%	2%
Faucet	189	243	432	8%	29	7.3	5.5	15%	5%
Leak	168	49	217	4%	15	3.7	2.8	3%	5%
Shower	986	1,231	2,217	44%	150	37.6	28.1	76%	28%
Toilet	1,920	0	1,920	38%	130	32.5	24.3	0%	55%
Toilet Leak	145	0	145	3%	10	2.5	1.8	0%	4%
Total	3,465	1,623	5,088	100%	345	86.2	64.4	100%	100%

Based on 14.75 day logging period

The flow traces provided information about the efficiency of the in-room fixtures. The shower flow rates, for cold water, averaged from 0.8 gpm to 1.4 gpm. When these rates are doubled to take into account the hot water usage it implies that the showers in the Inn meet the current low flow rating. During the 14.75 logged days, a total 527 flushes were counted, resulting in a per flush volume of 3.6 gallons per flush. This result indicates that the per room use of 86.2 gpd could be reduced further through the installation of ULF toilets.

It was possible to disaggregate outdoor water use at the Phoenix site from the main flow trace because the pattern from the automatic irrigation was regular and easily distinguished. Daily outdoor irrigation use during the logging period was estimated to be 5,810 gpd. There was no continuous water use at this site during the logging period.

Estimated end uses in hotels

Table 4.25 shows the estimated annual end uses of water in each of the hotels. Table 4.26 shows the water uses normalized on a per-room basis.

Table 4.25 Annual water use in field study hotels by end use (kgal)

Use Category	Irvine	Los Angeles	Phoenix	San Diego	Santa Monica
Indoor					
Bathtub		345	138		
Faucets	325	932	376	409	370
Showers	1,510	4,803	1,921	1,842	1,655
Toilets	1,405	4,151	1,663	1,774	1,595
Leaks	1,185	792	317	68	65
Total in-room use	4,425	11,023	4,415	4,093	3,685
Laundry	895		895	1,705	1,780
Ice making	120		156	232	
Other/misc. indoor	140	1,227	140	1,473	675
Indoor total	5,580	12,250	5,606	7,503	6,140
Continuous					
Cooling		5,850		0	1,840
Outdoor					
Irrigation		1,410	3,239		245
Swimming pool	310		400		430
Total	5,890	19,510	9,245	7,571	8,720

Table 4.26 Normalized annual hotel water use on a per room basis (gal/room/yr)

Use Category	Irvine	Los Angeles	Phoenix	San Diego	Santa Monica
Indoor					
Bathtub	0	2,331	986	0	0
Faucets	2,196	6,297	2,683	2,764	2,500
Showers	10,203	32,453	13,724	12,446	11,182
Toilets	9,493	28,047	11,881	11,986	10,777
Leaks	8,007	5,351	2,263	459	439
Total in-room use	29,899	74,480	31,536	27,655	24,899
Laundry	6,047	0	6,393	11,520	12,027
Ice making	811	0	1,114	1,568	0
Other/misc. indoor	946	8,291	1,000	9,953	4,561
Indoor total	37,703	82,770	40,043	50,696	41,486
Continuous					
Cooling	0	39,527	0	0	12,432
Outdoor					
Irrigation	0	9,527	23,136	0	1,655
Swimming pool	2,095	0	2,857	0	2,905
Total	39,797	131,824	66,036	51,155	58,919

Modeling Parameters

The modeling parameters that are available from the field site visits are summarized in Table 4.27.

Table 4.27 Modeling parameters for field study hotels

Parameter	Irvine	Los Angeles	Phoenix	Santa Monica	San Diego
Public/staff restrooms	2	11	5	5	1
Tank toilets	3	5	3	6	1
Valve toilets	0	3	3	0	0
Urinals	1	6	2	0	0
Faucets	2	6	5	6	1
Staff/guest showers	0	2	0	2	1
Guest bathrooms/restrooms	148	297	140	168	208
Tank toilets	148	297	140	168	208
Valve toilets	0	0	0	0	0
Urinals	0	0	0	0	0
Shower/bath	148	297*	140	168	208
Faucets	148	297	140	168	208

(continued)

Table 4.27 (Continued)

Parameter	Irvine	Los Angeles	Phoenix	Santa Monica	San Diego
Bar sink		297	0	0	0
Lounges	0	1	0	0	0
Kitchens	0	1	0	0	0
Restaurants	0	1	0	0	0
Banquet facility	0	1	0	0	0
Banquet meals/day	0	145	0	0	0
Shops	0	multiple	0	1	0
Laundries	1	1	1	1	1
Washing machines	4	2	3	4	5
Pools	800sf	400 sf	800 sf	320 sf	224 sf
Spa	1	1	0	1	0
Health club	0	1	0	0	0
Ice machine	8	12	6	7	4
Landscape (sf)	0	31,743	22,672	unknown	0
Pavement washing/week	7	2	7	1	0
Leaks (gal./hour)	135	unknown	22	unknown	9
Fountain	0	1	0	0	0
Water treatment	2-19kgal	2	2	1	1
Cooling tower (tons)	0	2 @ 300t	0	1@?	0
Inflow TDS (ppm)		750		550	
Concentration ratio		1.9		1.33	
Evaporative condensers	0	0	0	0	0
Swamp cooler	0	0	0	0	0
Hot water boilers	3	2	0	0	0
Auto dishwashers	0	1	0	0	0
Scullery nozzles	0	2	0	0	0
Garbage disposals	0	2	0	0	0
Garbage strainer	0	1	0	0	0
Dishwashing sink	0	3	0	0	0
Floor hose	0	1	0	0	0
Utensil bins	0	3	0	0	0
Pot sink	0	4	0	0	0
Food prep sinks	0	10	0	0	0
Hand wash sinks	0	5	0	0	0
Utility sink	8	21	8	11	12

*Large size approximately 40-50 gallons

High Schools

The largest and most complex institutional users selected for field investigations were the public high schools. There were many factors that added to the complexity of water use at these sites. Most of the public high schools in the five study cities were on large campuses that were served by multiple water meters. Most of these schools had more than 2000 students. It proved difficult for the water departments to obtain accurate information on the location and model of each and every water meter at the schools. When meters were located in the field, they often proved to be older mechanical meters that were not compatible with the data loggers. In these cases it was necessary to request that the meters be replaced, or select a new school. In the end, it was only possible to find suitable high schools in four of the five participating cities.

During the site visit to a Los Angeles high school a defective water meter was discovered. It turned out that one of the main meters at the site had not recorded any flow for at least a year. A second indoor meter at this school was not discovered until after the logging period, so no flow trace data were available for the portion of the school served by those meters.

In the four participating high schools, only a single location was found suitable for installation of a sub-meter to provide data on bathroom use.

General Information

General information on the four field study high schools is shown in Table 4.28. The smallest school in this study was in Phoenix that had only 2186 staff and students. The other three schools had from 2640 to 3850 staff and students. The study high schools ranged between 220,000 and 325,000 square feet of floor area. Irrigated landscape areas ranged from 395,000 to 1,300,000 square feet. Of the four high schools, the Irvine site was the only one that used non-potable water to irrigate.

The number of water meters serving exclusively indoor purposes ranged from 1 at the school in Phoenix to 8 at the school in Santa Monica. The two indoor meters at Irvine fed a looped domestic system. During the logging period, one of these meters was turned off and data were collected from the other meter. The existence of multiple meters complicated the data collection effort, but actually aided the disaggregation provided that each meter served a separate group of uses and users. Parallel meters that served a looped system, like the system at Irvine, were not desirable since the flow for the same group of users was split between two meters, making it difficult to interpret the flow trace data.

Two of the high schools operated on a traditional school year calendar and the other two followed a year-round calendar. Two schools had swimming pools as part of the gym complex and only one had a cooling tower for its air conditioning.

Table 4.28 General information on four field study high schools

	Irvine	Los Angeles	Phoenix	Santa Monica
Number of students/staff	2,640	3,850	2,186	3,065
Building footprint (sf)	224,652	253,357	325,000	220,000
Number of indoor meters	2	2	1	8
Number of outdoor meters	1	2	2	2
Annual operating days	180	340	180	340
Irrigated area (sf)	1,300,000	579,125	784,000	395,000
Cooling (tons)	0	0	600	0
Pool (sf)	5,760	0.00	0.00	11,250

Annual and Seasonal Use

Billing data were used to estimate annual and seasonal water use at each school. These results are shown in Table 4.29. The range in indoor use was from 2485 kgal in Irvine to 11,467 kgal in Phoenix. The high use in Phoenix can be explained by the presence of the cooling tower. The annual use at the Los Angeles site was estimated from a combination of logged data and meter data. As mentioned above, a meter was found after the logging that was thought to be indoor only, but based on the high water use at this meter and the fact it is closest to some major outdoor uses, it is suspected that it may actually serve outdoor uses as well. Not having flow trace data made it impossible to verify its use.

Of the four schools, the lowest water user by far is the Santa Monica site, which uses less than 9 million gallons per year. The highest water use is the Phoenix site, at over 36 million gallons. The high use there is clearly due to cooling and irrigation uses.

Table 4.29 Annual and seasonal uses at four field study high schools (kgal)

	Irvine	Los Angeles	Phoenix	Santa Monica
Total annual use (97) (kgal)	24,549	26,371	36,525	8,782
Annual indoor use (97) (kgal)	2,495	5,250*	11,467	2,708
Annual outdoor use (97) (kgal)	22,055	21,121	25,058	6,074
Average daily use (kgal)	67.3	72.2	100.1	24.1
Average daily indoor use (kgal)	6.8	14.4	31.4	7.4
Average daily outdoor use (kgal)	60.4	57.9	68.7	16.6
Season use (kgal)	17,999	unknown	20,287	3,953
Non-seasonal use (kgal)	6551	unknown	16,238	4,829

*This was estimated from logged data since the main domestic water meter was broken. A second meter was found after logging. It was listed as indoor only, but this could not be verified.

Logging Data

The water use at the four field study high schools during the logging periods is shown in Table 4.30.

Table 4.30 High School water use during logging periods

	Irvine	Los Angeles	Phoenix	Santa Monica
Logged average day (kgal)	9.10	52.94	106.70	16.4
Logged indoor average day (kgal)	9.10	2.64	17.17	9.1
Logged outdoor average day (kgal)	na	50.30	77.61	7.8
Peak instantaneous demand (non-irrigation) (gpm)	60	39	46	41
Length of trace (days)	7.0	6.8	2.8	15.0

Disaggregation of Flow Trace Data

In three of the four high schools logged, data were obtained which were sufficient to disaggregate use into indoor, outdoor and continuous uses. At the Los Angeles site estimates were made based on the available information, but due to lost and broken meters there is uncertainty in the results. At Irvine it was possible to make reasonable estimates of indoor end uses based on data obtained from a sub-meter installed for this project. At Santa Monica High it was possible to make reasonable estimates of indoor end uses because of the number of meters (10) that serviced individual school buildings where end uses tended to be more homogenous.

For example there were meters that served only classroom buildings, only gym buildings, and only administration and cafeteria buildings.

Estimated End Uses at High Schools

The results of the disaggregation are shown in Table 4.31 and Table 4.32 shows the results normalized on the basis on indoor square footage and Table 4.33 shows the results normalized on the basis of the number of students and staff.

In the three sites from which the most reliable data were obtained: Irvine, Phoenix, and Santa Monica indoor use ranged from 1.5 to 2.6 million gallons per year.

Table 4.31 Estimated annual end uses at four field study high schools (kgal)

	Irvine	**Los Angeles**	**Phoenix**	**Santa Monica**
Indoor				
Toilet	715			630
Urinal	280			569
Faucet	230			505
Shower	115			143
Kitchen	154			214
Misc. uses				207
Total indoor use	1494	4900	2629	2268
Continuous				
Cooling			7,500	
Other continuous (leaks)	805	350	1,371	344
Swimming pool	195			95
Total in-building use	2,494	5,250	11,500	2707
Outdoor				
Outdoor	22,055	21,121	25,058	6074
Total Use	24,549	26,371	36,558	8781

Table 4.32 Normalized annual use per square foot of building area at high schools (gal)

Gal./sf of school area/year	Irvine	Los Angeles	Phoenix	Santa Monica
Indoor				
Toilet	3.2			2.9
Urinal	1.2			2.6
Faucet	1.0			2.3
Shower	0.5			0.7
Kitchen	0.7			1.0
Misc. uses				0.9
Total indoor use	6.7	19.3	8.1	10.3
Continuous				
Cooling			23.1	
Other continuous (leaks)	3.6	1.4	4.2	1.6
Swimming pool	0.9			0.4
Total in-building use	11.1	20.7	35.4	12.3
Outdoor				
Outdoor (per sf of irrigated area)	17.0	36.5	32.0	15.4
Total Use	28.1	57.2	67.3	27.7

Table 4.33 Normalized annual water use per person at field study high schools

Gal./student or staff /year	Irvine	Los Angeles	Phoenix	Santa Monica
Indoor				
Toilet	271			206
Urinal	106			186
Faucet	87			165
Shower	44			47
Kitchen	58			70
Misc. uses	0			68
Total indoor use	566	1273	1203	740
Continuous				
Cooling			3431	
Other continuous (leaks)	305	91	627	112
Swimming pool	74			31
Total in-building use	945	1364	5261	883
Outdoor				
Outdoor	8354	5486	11463	1982
Total Use	9299	6850	16724	2865

Modeling Parameters

The information that was available for the model parameters is listed in Table 4.34. In many cases it was not possible to do accurate counts of individual fixtures limited access in the schools. In other cases we were provided with reports from previous audits that upon review did not contain the necessary information.

Table 4.34 Model parameters from field study high schools

Modeling Parameter	Irvine	Los Angeles	Phoenix	Santa Monica
Restrooms	23	31	56	67
Tank toilets	0	0	0	0
Valve toilets	100	109	148	345
Urinals	77	60	78	155
Faucets	65	60	100	122
Classroom faucets	174			
Drinking fountains	22			54
Service sinks	8			20
Gym showers	25			34
Swimming pool	1-72x80x6	0	0	1-72x80x6
Clothes washer	1		3	
Leak (gal/hour)	122	20	unknown	50
Cooling tower (tons)	0	0	600	0
Feed line (ppm)			550	
Blow down (ppm)			1270	
Concentration ratio			2.31	
Swamp cooler	1	0	4	0
Water treatment			1	0
Cafeteria	1	1	1	1
Dishwashers	0	0	1	0
Kitchen faucets	3			3
Disposals	1	1		1
Food prep sinks		4		3
Hand wash sinks		2		1
Ice machine	1	1	3	0
Meals served/day		1250/day		
# of boilers	1	4	1	6

CHAPTER 5

GENERALIZED MODELS OF CI WATER USE

INTRODUCTION

This chapter presents several statistical models for explaining water use among commercial and institutional water use customers. The purpose of this analysis is to develop and interpret econometric end use models for different classes of commercial and institutional customers. The objectives of the econometric end use models are to provide predictors of water usage and to show how certain water use determinants affect water use among the five related categories of the CI sector. The various models can be used as a practical tool for identifying CI customers with high potential for water conservation.

DATA SOURCES AND STRUCTURE

Data for the end use modeling were collected from existing electronic databases and hard-copy surveys that contained on-site audit information of CI customers. The Metropolitan Water District of Southern California, City of Phoenix Water Services Department, Southwest Florida Water Management District and the City of Denver provided these databases of CI audits. The majority of audit data used in this study was contained in the database provided by Metropolitan. The data from the various sources were combined to create one data set per CI category. Additional local weather data including maximum temperature, cooling degree-days, and precipitation, were added to the data sets so that the impact of weather on water use could be examined.

The data for model estimation consisted of five separate databases, each corresponding to a type of establishment selected for this study, namely:

1. Restaurants
2. Hotels and motels
3. Supermarkets
4. Office buildings
5. Schools

Each audit database had monthly and/or bimonthly water consumption data available for a period of usually one or two years. Later, because of the resulting nature of the water use data, these were converted into an annual water use total over a billing year. In the regression models, these totals were scaled to a calendar year basis and converted into gallons per day per establishment. These annual totals became the dependent variables for each of the CI category models.

To help explain water use, three types of explanatory variables were available for each establishment: (1) indicator variables that designate the presence (or absence) of specific end uses at the establishment, (2) variables measuring the magnitude (or size) of water-using activity for some specific end uses, either as continuous or discrete measurements, and (3) variables that are common to all or most end uses. In Appendix B, Tables B.1 through B.5 contain a list of variables in each category that were considered for each of the five CI classes.

All of these listed variables were potentially acquirable from the on-site audit data. Obtaining values for these potential variables depended upon the specific end use and if the variable indicated a presence or a count. The number and type of toilets, irrigation area, and the presence of cooling towers were usually identified in an audit. However, measurements such as the size of specific fixture or the number of fixtures present that could supplement this visually inspected data were not acquired consistently for the establishments. This was probably the result of differences in auditing techniques and investigative detail provided by the different companies and agencies that performed these audits.

The following sections provide a statistical snapshot of the audit databases.

OVERVIEW OF ESTABLISHMENT LEVEL DATA

Office Buildings

A total of 74 office buildings were contained in the database, reporting water audits in 27 cities across four states (Arizona, California, Colorado, and Florida). Average daily water use per office building is 27,685 gallons (n = 72). As shown in Table 5.1, the average building area of the sample of office buildings is 175,632 square feet. The average irrigated area for these office buildings is 60,592 square feet.

Table 5.1 also provides data on average daily water use distributed according to various descriptive variables as reported in the audits. The average daily water use per employee in the sample of office buildings is 137 gallons. The average daily water use per square foot of building area is 0.2 gallons. Thus, office buildings in the sample use 200 gallons of water per day for every 1,000 square feet of building area. Applied across irrigated area, the average daily water use for the group of office buildings is 2.9 gallons per square foot of irrigated area.

Table 5.1 Office building characteristics and average water use

Variable	***n***	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**
Average annual use (kgal)	72	10105.0	20218.4	161.6	139470.6
Average daily use (kgal)	72	27.7	55.4	0.4	382.1
Average daily water use per employee (gal./employee)	67	136.8	456.5	3.6	3,635.5
Average daily water use per irrigated area (gallons/sf)	57	2.9	13.4	0.05	96.9
Average daily water use per building area (gallons/sf)	72	0.2	0.4	0.00	2.7
Average daily water use for cooling tower (gallons)	44	31,800	43,193	3,812	276,900
Number of employees	69	500	590	6.0	3,000
Number of toilets	67	50.7	53.4	3.0	260.0
Irrigated area	67	60,592	79,044	0.0	435,600
Building area (sf)	74	175,631	160,805	6,000	1,300,000
Number of stories	74	5.1	8.7	1.0	54.0
Number of separate buildings	74	2.1	3.2	1.0	26.0

Hotels and Motels

The audit database consisted of a total of 100 hotels and motels from 39 cities in four states (Arizona, California, Colorado, and Florida). The average daily water use per hotel in the sample is 51,531 gallons (n = 97). The majority of hotels had at least one swimming pool. Table 5.2 provides other descriptive information on hotels and motels. For example, the average number of individuals employed among the sample is 116 people. Also, the average number of rooms found at the properties in the sample is 265. Average daily water use per employee for the hotel or motel sample was 668 gallons. Average daily water use per available room among the sample is 162 gallons.

Table 5.2 Hotel and motel characteristics and average water use

Variable	*n*	Mean	Standard Deviation	Minimum	Maximum
Average annual use (kgal)	97	18809.0	36410.0	1668.0	307932.2
Average daily use (kgal)	97	51.5	99.8	4.6	843.7
Average daily water use per employee (gal./employee)	88	668.0	567.2	83.4	3,491
Average daily water use per building area (gallons/sf)	97	0.4	0.6	0.03	4.9
Average daily water use per irrigated area (gallons/sf)	83	24.0	175.8	0.03	1601
Average daily water use per room (gallons/room)	93	161.9	123.1	40.1	1214
Number of employees	90	116.1	176.6	3.0	1,000
Building area (sf)	100	170,634	187,290	12,850	1,500,000
Irrigated area (sf)	100	88,600	423,984	0.0	4,051,080
Number of rooms	94	265.1	262.6	28.0	1,576

Supermarkets

A total of 33 supermarkets and grocery stores were sampled from 18 locations in two states (California and Arizona). The average daily water use per grocery store is 7,703 gallons (n = 33). As shown in Table 5.3, the average number of individuals employed by the grocery stores in the sample is 54 people. Further, the average building area is 39,776 square feet and the average number of customers in a week is 16,037 people.

The average daily water use per employee in the group of grocery stores is 175 gallons, while, the average daily water use per customer is 4 gallons. The average daily water use per square foot of building area is 0.2 gallons. Therefore, a supermarket's daily water usage is approximately 200 gallons for every 1,000 square feet of building area.

Table 5.3 Supermarket characteristics and average water use

Variable	*n*	Mean	Standard Deviation	Minimum	Maximum
Average annual use (kgal)	33	3155.7	1264.6	1668.0	6659.4
Average daily use (kgal)	33	7.7	1.7	4.6	11.2
Average daily water use per employee (gal./employee)	33	174.9	88.6	50.8	489.9
Average daily water use per customer (gal./customer)	33	4.1	1.5	0.6	7.0
Average daily water use per building area (gallons/sf)	33	0.2	0.1	0.1	0.4
Number of employees	33	53.6	28.6	17.0	165.0
Number of customers	33	16,036.7	12,019.3	7,700.0	77,000.0
Building area (sf)	33	39,775.8	14,744.9	20,000.0	81,230.0
Irrigated area (sf)	33	2,363.6	8,302.2	0.0	45,000.0
Number of toilets	33	5.2	3.6	0.0	16.0

Restaurants

A total of 87 restaurants were sampled from 38 locations in three states (California, Florida, and Colorado). The average daily water use per restaurant is 7,736 gallons (n = 85). Table 5.4 provides descriptive information concerning average characteristics of restaurants. For example, the average number of individuals employed in the sampled restaurants is 46. Furthermore, the average number of meals that are served in a week is 4,667, while the average number of customers per week is 4,701.

Table 5.4 also provides data on average daily water use according to various descriptive variables. For example, the average daily per employee water use for a restaurant is 233 gallons. In addition, the average daily water use per meal is 16 gallons. Moreover, the type of restaurant greatly influences the magnitude of water consumption. The data revealed that the Chinese restaurants in the sample have the highest daily water use (15,479 gallons per day [gpd]) and fast food restaurants have the lowest use (4,076 gpd). Investigations have shown that many Chinese restaurants never turn their faucets off because it facilitates the ability to rinse hot woks.

Table 5.4 Restaurant characteristics and average water use

Variable	*n*	Mean	Standard Deviation	Minimum	Maximum
Average annual use (kgal)	85	2823.6	1795.9	357.5	12574.6
Average daily use (kgal)	85	7.7	4.9	1.0	34.5
Average daily water use per employee (gallons/employee)	85	233.0	227.4	26.6	1,379.6
Average daily water use per building area (gallons/sf)	85	1.1	0.8	0.1	4.2
Average daily water use per irrigated area (gallons/sf)	52	2.4	2.7	0.2	10.0
Average daily water use per customer (gallons/customer)	85	12.8	9.4	1.0	53.2
Average daily water use per meal (gallons/meal)	85	16.1	19.8	1.4	150.4
Number of employees	87	46.0	29.3	6.0	200.0
Building area	87	10,653.7	9,484.4	2,200.0	60,00.0
Irrigated area	87	4,588.5	7,213.4	0.0	44,000.0
Number of customers	87	4,701.1	1,588.8	1,400.0	12,000.0
Number of meals	87	4,666.9	2,879.1	910.0	21,000.0
Seats	87	189.9	24.2	100.0	299.0
Number of toilets	87	5.3	2.2	2.0	13.0

Schools

The audit sample consisted of a total of 139 schools from 35 locations in four states (Arizona, California, Colorado, and Florida). As shown in Table 5.5, the average number of students attending the sampled schools is 1,449 pupils. The average number of school employees is 110 individuals. On average, each school contains 44 toilets and 18 showers. The large range of values for toilets, showers, and other variables, such as building area and irrigated area, reflect the range of schools from grade and junior highs to college campuses.

With respect to average daily water use, the data shows that each school, on average, uses 31,761 gallons per day (n= 138). However, it is worthwhile to delineate average daily water use according to type of school. As shown in Table 5.5, colleges and universities have a higher average daily water use than senior high, junior high, and elementary schools. Furthermore, the data shows that elementary schools have the lowest average daily water use among the types of schools audited.

Table 5.5 provides data on average daily water use according to other selected variables. The average daily water use per employee in the school group is 341 gallons. The average daily water use per student is 24 gallons.

Table 5.5 School characteristics and average water use

Variable	***n***	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**
Average annual use for all schools (kgal)	138	11592.8	11446.0	1352.4	71165.5
Average daily use for all schools (kgal)	138	31.8	31.4	3.7	195.0
Average daily water use per employee (gal./employee)	138	341.2	216.3	29.9	971.0
Average daily water use per pupil (gal./student)	137	24.0	14.0	2.6	84.2
Average daily water use per building area (gallons/sf)	138	0.3	0.3	0.03	1.5
Average daily water use per irrigated area (gallons/sf)	128	1.4	14.3	0.01	161.8
Average daily water use for cooling tower (gallons)	31	41,525	42,502	7,684	194,973
Number of employees	138	109.7	210.2	16.0	2,451
Number of pupils	137	1,449	2,155	200	20,643
Building area	138	135,984	76,159	22,000	500,000
Irrigated area	129	408,625	386,976	0.0	1,960,000
Number of showers	138	17.7	32.0	0.	146.0
Number of toilets	127	43.9	50.0	9.0	424.0
Average daily water use for grade schools (gallons)	60	13,260	7,792	5,100	41,420
Average daily water use for middle schools/junior high schools (gallons)	29	24,520	10,910	4,931	46,420
Average daily water use for high schools (gallons)	38	52,040	27,490	3,705	123,200
Average daily water use for colleges/universities (gallons)	8	103,400	54,360	32,790	195,000

Transition to Modeling

Statistical modeling of audit databases was constrained by several limitations of the samples. One limitation of the analysis is the small sizes of the samples. Small CI class sample sizes place constraints on the researcher's abilities to generalize the findings to larger populations. The relatively few geographic and climatic areas represented in the sample also limited analysis. Another limitation of the samples is the large number of missing or suspect values among theoretically important variables. The high number of missing or suspect values for these variables made statistical modeling a difficult process particularly in the application of the conditional demand analysis methodology (see below).

MODELING APPROACH

Proposed Methodology

Conditional demand analysis (CDA) was proposed as the econometric methodology to model CI water demand. The CDA approach can provide an indirect measure of water used for a specific purpose (i.e., end use) based on total metered water use in CI establishments and the presence (or absence) of specific purposes of water use (or a measure of size of water-using activity) obtained from survey data. The basic premise of the CDA method is that the variance of water use across different establishments of the same type can be explained by the mix and magnitude of water-using activities found in each establishment.

The following section gives a brief background on the CDA model specification and provides a description of the available observations on water use and explanatory variables.

Conditional Demand Analysis

Electric utilities have used conditional demand analysis for estimating energy consumption for specific residential end uses (e.g., heating, air conditioning, refrigeration, clothes dryers, etc.) The CDA method uses billing data for energy use by individual households and survey data on the presence (or absence) of specific appliances to derive estimates of average energy use for each purpose. Within the electric energy context, the CDA model specification is based on two assumptions:

1. Observed total use of energy in any given month is a summation of energy used by all electric appliances, fixtures and heating or air conditioning systems, and
2. Energy use by each appliance or system depends on a number of external factors (such as a weather, price, number of residents, income, etc.)

In the study of nonresidential water demands, the CDA approach was proposed as a means of estimating the quantities of water used for specific purposes without the necessity of directly metering water flows to each end use.

The basic linear form of a conditional *water* demand model is based on the assumption that the observed annual water use at a given C&I establishment is a sum of all end uses, as follows:

$$Q_k = \sum_i E_{ki} \tag{5.1}$$

where $Q_k =$ average annual water use in gallons per day at the establishment k

$E_{ki} =$ average quantity of water used for end use i

Conceptually, the conditional water demand model makes it possible to estimate water used for each purpose through the use of indicator variables, D_i, which indicate whether a given end use is present at the establishment. Because some end uses are present at all establishments and there are always end uses that are unknown, the estimates of average usage can be obtained only for those end uses that are present in some establishments and absent in others. Because of this limitation the model is usually specified as:

$$Q_k = a + \sum_i b_i D_{ki} + \varepsilon_k \tag{5.2}$$

where a = equation's intercept

b_i = regression coefficient for specified end use

D_{ki} = Binary variable denoting the presence of end use in establishment k

ε_k = a random error term that denotes the difference between actual Q_k and Q_k as estimated from the model

Because the samples of establishments used in this study have many common end uses, only a limited number of end uses may be quantified. However, the majority of common end uses differ in terms of their size or count. For example, all restaurants have restrooms (a common end use) but the number of restrooms and the number of water-using fixtures in these restrooms differ among the restaurants.

Within the context of the CDA model, the availability of some measure of end use size or a count of the fixtures and appliances comprising each end use may permit estimation of average water use for the common end uses. The model can be re-specified as follows:

$$Q_k = a + \sum_i b_i D_{ki} + \sum_j c_j S_j + \varepsilon_k \qquad (5.3)$$

where S_j = a count or a measure of size of a common end use j
c_j = regression coefficient of common end use j

Further expansion of the CDA model is also possible by recognizing that the quantity of water used for a specific purpose may vary from establishment to establishment when the values of the predictors of that end use vary. In the context of the model shown in equation 5.3 this implies that the values of a, b_i, and c_j, can be expressed as linear functions of the relevant explanatory variables. For example, if b_i, represents the dishwashing end use in the sample of restaurants, theoretically it could be expressed as:

$$b_{dw} = \alpha_{dw} + \beta_{dw} M + \delta_{dw} P + \varphi_{dw} N + \varepsilon_{dw} \qquad (5.4)$$

where M = number of meals served
P = marginal price of water (including sewer charges)
N = number of employees

Similarly, the coefficient b_i for landscape irrigation could be expressed as:

$$b_{ir} = \alpha_{ir} + \beta_{ir} A + \delta_{ir} P + \varphi_{ir} W + \varepsilon_{ir} \qquad (5.5)$$

where P = marginal price of water (including sewer charges)
A = irrigable area

W = local climate variables

These equations can be substituted for b_i in equation 5.3 together with similar expressions for other end uses. For these two end uses with a nested specification, and adding a count specification for icemakers and a binary specification for the presence of a bar, the resultant model would be:

$$
\begin{aligned}
Q_k = a + (\alpha_{dw} + \beta_{dw}M + \delta_{dw}P + \varphi_{dw}N + \varepsilon_{dw}) \cdot D_{dw} \\
+ (\alpha_{ir} + \beta_{ir}A + \delta_{ir}P + \varphi_{ir}W + \varepsilon_{ir}) \cdot D_{ir} + b_{ice}K_{ice} + b_{bar}D_{bar} + \varepsilon_k
\end{aligned}
\tag{5.6}
$$

After eliminating the parentheses, the form of the equation would be:

$$
\begin{aligned}
Q_k = a + \alpha_{dw}D_{dw} + \varepsilon_{dw}D_{dw} + \beta_{dw}M \cdot D_{dw} + \delta_{dw}P \cdot D_{dw} + \varphi_{dw}N \cdot D_{dw} \\
+ \alpha_{ir}D_{ir} + \varepsilon_{ir}D_{ir} + \beta_{ir}A \cdot D_{ir} + \delta_{ir}P \cdot D_{ir} + \varphi_{ir}W \cdot D_{ir} + b_{ice}K_{ice} + b_{bar}D_{bar} + \varepsilon_k
\end{aligned}
\tag{5.7}
$$

The above equation can be further expanded by adding nested specifications or binary variables for some end uses (without specifying any nested model) and by adding more variables designating counts (or sizes) of other end uses.

Evaluation of CDA Models

The study team solicited the opinions of three expert econometricians with regard to the validity of the CDA approach and certain other estimation issues. The particular questions and review comments by the panel of econometricians are provided in Appendix C of this report. Generally, the panel saw no obvious fatal flaws in the conceptual design of the proposed modeling procedures, and the study team then proceeded in the development of the CDA models using linear (i.e., untransformed) equations. As discussed in the next section, intermediate results showed clear practical limitations associated with the data elements and sample size, and consequently the study team modified its initial CDA modeling approach.

Modifications of CDA Models

The theoretical specifications of the CDA models described above were modified depending on the availability of data and the initial modeling results. The following specific changes were made in deciding on the specification of the independent variables in the final model.

1. The binary and continuous independent variables were first selected to match the theoretical models as closely as possible. However, the availability of indicator and size variables in the audit databases limited the number of end uses that could be specified by either binary or continuous variables or both. Missing values on some variables also limited the inclusion of some variables as the number of observations with valid values would decrease or even produce an empty set.
2. Additional modification of the theoretical model involved an initial examination of estimated model coefficients. Coefficients that were not statistically significant were evaluated in order to determine if the result was caused by the inclusion of pairs of intercorrelated variables. If this was the case, only one variable was selected.
3. Another modification was related to the sign of the estimated coefficients. If the signs were other than expected, then the variables were removed from the final equation, because their inclusion would prevent a rational interpretation of the model. In most cases, the wrong sign of the variables was a direct result of the data structure (and small sample size) where some outliers in the data would have a strong effect on the estimated slope parameter.
4. Given the limitations of the data, the final specifications of the water use models were selected based on the following criteria:
   (a) The model explained a significant proportion of variance in the dependent variable.
   (b) The binary and continuous variables included in the model were adequate for estimating major end uses.
   (c) All coefficients of the model were at least marginally significant and had a rational sign.

The modified models are presented and interpreted in the next section.

MODELING RESULTS

The results of statistical modeling are presented below for each of the five CI sectors under investigation. As indicated above, the sample establishments and their associated characteristics were obtained from existing audit data. The audit databases, therefore, provide the variable values for water use (expressed in annual daily averages) and the explanatory variables that are specified in the models.

Regression statistics include the estimated coefficient, standard error of the coefficient estimate, t-statistic, and p-value. The standard error is an indicator of the variation of the estimated coefficient. The t-statistic is derived from dividing the estimated coefficient by the standard error. This ratio is used to test if the coefficient estimate is equal to zero. A larger t-statistic (e.g., 1.90) is better. The p-value indicates the error probability or level of significance of the estimated coefficient. A smaller p-value (e.g., 0.05) indicates a greater likelihood of accepting the relationship between the variable and water use. The significance level of acceptability indicated by the t-statistic and p-value varies with the number of observations (N) and the number of variables in the model.

Office Buildings

Table 5.6 presents the estimated water use model for office buildings. The model explains about 60 percent of the variation in average daily water usage. As expected, average daily water use increases as the number of individuals employed in the building increases. Each person employed in an office building accounts, on average, for an additional 13.5 gallons of water usage per day, holding everything else in the model constant.

Another important factor pertaining water usage in office buildings is the number of customers that visit the building on an average day. The variable that represents the ratio of toilets to employees serves as a proxy variable for the amount of traffic flow for a building. It is theorized that a building with a higher ratio of toilets to employees also has a higher traffic flow of customers. The greater number of toilets relative to the number of employees was assumed to represent the potential and likelihood that there are more visiting customers. This is confirmed by the model, in that office buildings with a higher ratio of toilets to employees experience a higher level of daily water usage. The average toilet to employee ratio was 0.1 (or 10 employees per toilet). The estimated coefficient indicates that an increase in the toilet-to-employee ratio from 0.1 to 0.2 (i.e., a change from 10 to 5 employees per toilet) would be associated with an additional water usage of 579 gallons per day.

For office buildings with cooling towers, daily water use attributed to cooling needs is estimated to be 0.023 gallons for every square foot of building area. Therefore, a 100,000 square foot office building with a cooling tower would be expected to use an additional 2,300 gallons per day compared to an identical building without a cooling tower, everything else remaining the same. Concerning irrigation, the model indicates that office buildings average 0.082 gallons of water per day for every square foot of landscape area that is irrigated. Furthermore, average annual water use is shown to increase with air temperature, which also relates to cooling and irrigation demand.

Table 5.6 Model for estimating office building water consumption

Parameter	Coefficient Estimate	Standard Error	t	Prob > |t|
Intercept	-64,209.587	43,184.595	-1.49	0.1443
Irrigated area	0.082	0.019	4.33	0.0001
Employees	13.539	3.467	3.91	0.0003
Cooling tower (0/1) * Building area	0.023	0.012	1.90	0.0648
Toilets per employee	5,789.063	2,912.051	1.99	0.0532
Annual maximum temperature	892.860	577.351	1.55	0.1293

N = 49
R-square = 0.596
Root mean square error = 8,173.825
Dependent variable: Average daily water use (gallons) = 17,426.7

Hotels and Motels

Table 5.7 displays the coefficient estimates and related statistics of the water use model for hotels and motels. The model explains 98 percent of the variation in average daily water usage among the sampled establishments. The model is specified using the number of occupied rooms and total number of rooms as scaling variables.

Table 5.7 Model for estimating hotel and motel water consumption

Parameter	Coefficient Estimate	Standard Error	t	Prob > |t|
Intercept	-58,121.892	29,541.552	-1.97	0.0524
Occupied rooms	59.9777	15.555	3.86	0.0002
Occupied rooms * Restaurants (0/1)	46.7627	17.665	2.65	0.0097
Occupied rooms * Irrigated area	0.0004	0.000	49.09	0.0001
Cooling tower (0/1) * Total rooms	91.0968	11.778	7.73	0.0001
Annual maximum temperature	879.1885	406.442	2.16	0.0034
Annual precipitation	-155.3504	178.559	-0.87	0.3868

N = 91
R-square = 0.984
Root mean square error = 13,216.581
Dependent variable: Average daily water use (gallons) = 50,609.840

The estimated model coefficients show that average daily water use increases with the number of occupied hotel rooms. The marginal increase is nearly 60 gallons per occupied room per day. The presence of a restaurant, on average, increases daily water use per occupied room by an additional 46.7 gallons per day. In hotels with irrigated landscapes, the irrigation use contributes an additional 0.0004 gallons per square foot of irrigated landscape per occupied room. A similar relationship also holds for hotel central air conditioning systems with cooling towers. Average daily water use attributed to cooling needs is about 91 gallons per day for every available room (as all rooms are cooled regardless of whether or not they are occupied).

Average annual water use in hotels also is shown to increase with average annual air temperature and to decrease with an increased average rainfall. These effects are related to water use for irrigation and cooling purposes and can be used to increase or decrease the combined rates of additional use that are associated with these two purposes.

Supermarkets

Table 5.8 shows the estimated model for supermarkets and grocery stores. The model explains 48 percent of the variation in average daily water usage among the 33 sampled establishments. The model is specified using the number of employees as a scaling variable.

Table 5.8 Model for estimating supermarket water consumption

Parameter	Coefficient Estimate	Standard Error	t	Prob > |t|
Intercept	4,977.213	890.724	5.59	0.0001
Employees	12.626	9.161	1.38	0.1803
Building area	0.020	0.018	1.13	0.2680
Employees * Floral department (0/1)	23.619	9.354	2.52	0.0183
Employees * Seafood department (0/1)	18.457	11.094	1.66	0.1087
Employees * Water vending (0/1)	36.804	15.586	2.36	0.0263
Employees * Irrigation (0/1) * Irrigated area	0.002	0.001	2.00	0.0568
Employees * Food prep sink (0/1) * Number of food prep sinks	3.347	2.553	1.31	0.2017

N = 33
R-square = 0.479
Root mean square error = 1,420.446
Dependent variable: Average daily water use (gallons) = 7,702.820

Average daily water use increases as the number of individuals employed by the grocery store increases. Each person employed at a grocery store adds an estimated 12.6 gallons to the grocery store's total daily water use. Furthermore, the results of the regression analysis show that daily water use increases with the size of the supermarket's building area by an additional 0.02 gallons of water per day per square foot of floor area. Supermarkets with a floral department use 23.6 gallons more for every employee when everything else is held constant. Also, stores with a seafood department increase daily water use by 18.5 gallons for every person employed at the store. Those stores that provide water vending machines increase their daily water use by almost 37 gallons for every employee.

For supermarkets that irrigate, daily water use increases with irrigated area. The additional use averages 0.00173 gallons per day per employee per square foot of irrigated landscape. Finally, for supermarkets that have food preparation sinks, daily water use increases by 3.35 gallons per day per employee for each additional food preparation sink.

Restaurants

Table 5.9 shows the estimated water use model for restaurants. The model explains 68 percent of the variation in average daily water usage among the 77 sampled establishments.

Average daily water use is shown to increase by 25 gallons for every seating space available for customers. Each meal served at a restaurant is estimated to contribute an additional 0.54 gallons toward the restaurant's daily water consumption. Finally, each person employed at a restaurant increases the restaurant's daily water use by 25 gallons.

Additional use is associated with the presence of end uses that are represented by the number of fixtures. Each scullery nozzle is found to increase daily water use by 1,272 gallons. Likewise, each garbage disposal increases daily water use by 1,878 gallons.

The regression results show that type of restaurant also matters in predicting the restaurant's daily water use. Each meal served at a Chinese restaurant adds an additional 2.03 gallons daily to the 0.54 gallons that is expected at other types of restaurants. Also, Chinese restaurants use 1,097 gallons per day on average for every wok faucet that is present. The relationship between type of restaurant and amount of water usage is the opposite for fast food restaurants. Each meal served at a fast food restaurant reduces daily water use by approximately 0.49 gallons (indicating in conjunction with the number of meals variable, that each meal in a fast food restaurant contributes only 0.05 gallons to total water use).

Table 5.9 Model for estimating restaurant water consumption

Parameter	**Coefficient Estimate**	**Standard Error**	**t**	**Prob > |t|**
Intercept	-19,853.767	15,568.666	-1.28	0.2067
Seating	25.018	16.487	1.52	0.1339
Meals	0.544	0.202	2.70	0.0089
Employees	25.233	15.887	1.59	0.1170
No. of Scullery nozzles	1,271.742	809.410	1.57	0.1209
No. of Garbage disposals	1,878.147	1,237.839	1.52	0.1340
Meals * Chinese (0/1)	2.029	0.356	5.71	0.0001
Chinese (0/1) * Wok faucets	1,096.697	208.689	5.26	0.0001
Meals * Fast food (0/1)	-0.486	0.199	-2.44	0.0175
Annual maximum temperature	235.308	203.442	1.16	0.2516
Annual precipitation	-57.989	61.626	-0.94	0.3501

N = 77
R-square = 0.676
Root mean square error = 3,098.384
Dependent variable: Average daily water use (gallons) = 7,913.577

Climate also has an influence on daily water use for restaurants. Higher average annual temperatures are associated with higher water usage and greater annual rainfall reduces total water use. The temperature and rainfall effects relate to irrigation and cooling needs, which could not be adequately represented by separate indicator variables in the model.

Schools

Table 5.10 shows the estimated daily water use model for schools. The model explains 82 percent of the variation in average daily water use in the set of 125 schools.

The sanitary usage by pupils and employees is captured by three variables: number of toilets, number of showers, and number of employees. Each person employed at a school contributes an additional 66.2 gallons of water usage per day. The variables for toilets and showers are used to measure school size, under the assumption that more of these end uses are present with more pupils. For every added toilet, the sanitary water usage increases on average by 164.5 gallons per day. For every added shower, sanitary use increases by approximately 70 gallons per day.

Table 5.10 Model for estimating water use in schools

Parameter	Coefficient Estimate	Standard Error	t	Prob > |t|
Intercept	-12,449.770	7,973.051	-1.56	0.1211
Toilets	164.482	44.448	3.70	0.0003
Irrigated area	0.037	0.005	8.19	0.0001
Showers	69.961	50.907	1.37	0.1720
Pools	6,013.700	3,114.109	1.93	0.0559
Pools * College (0/1)	43,507.155	16,491.085	2.64	0.0095
Cooling towers * Building area	0.022	0.016	1.43	0.1568
Employees	66.180	37.020	1.79	0.0764
Annual cooling degree days	9.973	6.431	1.55	0.1237

N = 125
R-square = 0.820
Root mean square error = 13,304.427
Dependent variable: Average daily water use (gallons) = 30,478.076

Each swimming pool at a school is found to increase daily water use by 6,014 gallons. For colleges, which are likely to have large swimming facilities, each swimming pool on campus increases daily water use by an additional 43,507 gallons. Unfortunately, the database did not contain information on the dimensions of the swimming pools.

Irrigation of playing fields and landscapes is a significant end use in schools. Daily water use increases at a rate of 0.037 gallons per square foot of irrigated area. For schools with cooling towers, daily water use attributed to cooling needs is 0.022 gallons for each square foot of building area. Therefore, the model predicts that a school with 100,000 square foot of building area that is centrally cooled by a system with cooling towers would use 2,200 gallons of water per day. Similarly, the annual number of cooling degree-days is positively related to total water use, indicating that schools located in warmer climate zones would have higher combined rates of water use for cooling and irrigation.

Significant Modeling Variables

Table 5.11 presents a summary of variables that were found to be significant predictors of CI water use and which may be used to normalize water use for benchmarking purposes. There are three variables that are common across the CI categories; namely, the number of employees at a facility, the square footage of a facility, and the square feet of irrigated area. In addition to the common variables, there are specialized variables for each of the categories: the number of occupied rooms for hotels and motels, the number of daily transactions for supermarkets, the number of meals served for restaurants, and the number of students for schools.

Table 5.11 Significant modeling variables in five CI categories

Variable	Offices	Hotel/Motels	Supermarkets	Restaurants	Schools
Employees	✓		✓	✓	✓
Building area (sf)	✓	✓	✓	✓	✓
Irrigated area (sf)	✓	✓	✓		✓
Occupied rooms		✓			
Transactions			✓		
Meals served				✓	
Students					✓

In addition to these variables, weather variables such as maximum temperature, precipitation, and/or cooling degree days were also significant in the predictive models of water use.

CHAPTER 6

BENCHMARKING ANALYSIS

INTRODUCTION

Purpose of Benchmarking

The purpose of the benchmarking analysis is to determine whether the available data and statistical water use models presented in this report can be used to develop a set of benchmarks for the comparison of water use between similar commercial and institutional establishments.

Benchmarking Measures and Values

Benchmarking is a method used by businesses to measure their performance relative to the performance of other businesses. Benchmarking can also be used to assess the efficiency of water use in a business establishment. A water use benchmark should allow the business manager to determine if the amount of water used within the establishment is reasonable or if it falls within an expected range. Additional benchmarks may be used to determine how much water use would be expected if water were used efficiently for all purposes of use found within the establishments.

Benchmarking measures are ratios that express water use in ways that allow meaningful comparisons of use between different establishments. The primary purpose of a benchmarking measure is to "normalize" water use with respect to the size of the establishment.

A benchmark value, in the context of this study, represents a quantity of expected water use. When normalized with respect to the size of the establishment (or the magnitude of its business operations), this value would represent a given unit use of water such as gallons per employee per year, or gallons per square foot per year, that represents an average achievable level of efficiency. A detailed analysis of end uses in a sample of establishments would be required to determine other measures of efficiency that can be represented by a benchmark value.

Benchmarking Assumptions

The development of benchmarking measures for each of the five types of CI establishments covered by this study is based on the following assumptions:

1. Total annual water use in a sample of establishments that belong to the same category varies not only because of the differences in efficiency of water use, but also because the establishments may differ in size and with respect to the mix of specific end uses that are present, as well as other factors which affect water use. A meaningful comparison of usage levels can be performed only if "corrections" are made to account for the factors other than efficiency.
2. Most meaningful benchmarking measures are those for individual purposes of use (end uses), given that these end uses are "normalized" for establishment size and other variables that are not related to the efficiency of use.
3. Benchmarks for aggregate use (e.g., total use in the establishment, or indoor sanitary use) can be derived by adding together the products of benchmark values and size values for individual end uses and by expressing the result in terms of a common scaling value, such as square feet of building area or number of employees. Therefore, the resultant benchmark value of water use would be different for each establishment.
4. The statistical models should allow a separation of major end uses from the total establishment water use, thus permitting more meaningful predictions of average rate of use within a category of establishments.

Efficiency-in-Use Benchmarks

Benchmarks of expected levels of usage are not the same as benchmarks that designate efficient levels of use. In order to designate a benchmark value for efficient use, it is necessary to determine whether the end uses that comprise the total establishment use are efficient in terms of the available technology or established practices in water-using operations. The data used in this study did not provide sufficient information for establishing precise efficiency benchmarks. However, the variability of use among different establishments, when "normalized" for establishment size and other variables, provide an indirect indication of current practices. These in turn can be thought of as the existing average levels of efficiency in use.

DEVELOPMENT OF BENCHMARKING MEASURES

While the estimated statistical models of water use for each of the five categories of establishments can be used to derive benchmarks for average levels of water use, it is helpful to examine the variability of water use directly from the data. A detailed examination of the data is helpful in determining which scaling variables and what level of disaggregation of total water use (into individual end uses) are best for developing benchmarking measures.

Consequently, the development of benchmarking measures was performed using the following four separate analytical steps:

1. The field study data and associated billing data obtained for 5 establishments in each of the five categories provided by the field studies were examined first in order to determine the variability of various benchmarking measures among the five establishments.
2. The results from the direct measurement field study data were compared to the data from the larger sample of the audited establishments used in model development. The audit data contained water balance calculations that provided estimates of water used for major purposes (primarily cooling and irrigation) within each establishment. These estimates were used to determine average rates of water use using alternative scaling variables that normalize use.
3. The estimated statistical models were used to replace the estimates of water use for major purposes with model predictions. The predicted values of water use for major purposes (i.e., indoor or base use, irrigation and cooling) were divided by scaling factors and compared to rates obtained from the audit data.
4. In the final step, the summary results from all three previous steps were tabulated and compared in order to select the values to represent benchmarks of water use.

The results of each step are presented for each category of establishments in the following sections. The working tables for steps 2 and 3 containing all valid cases from the audit data are included in Appendix D and Appendix E.

BENCHMARKING RESULTS

Supermarkets

Benchmark Usage Values from Field Studies Data

The direct measurement field studies of five supermarkets revealed that a major water usage was for cooling towers. The results of the analysis of flow trace data and billing records allowed the researchers to estimate the quantities of water used for each major purpose. Further analysis of these results was performed to determine the values of use for selected benchmark measures. The results are compared in Table 6.1.

The total water use in the five supermarkets ranged from 3,765 kgal per year to 5,075 kgal per year. When used as a benchmarking value, one could state that total water use in a supermarket similar to the five examined in the field studies should be in the range of 4,000 to 5,000 kgal per year. However, all five stores used large amounts of water for evaporative cooling and two stores had significant use for landscape irrigation. Therefore the benchmark range of 4,000 to 5,000 kgal per year would not be applicable to stores located in cooler and wetter climatic zones where there is little need for space cooling or outdoor irrigation. A better benchmark would be water use net of these two major uses. The results in Table 6.1 show that indoor use ranged from 1,215 to 1,685 kgal per year. In terms of benchmark values, one should expect that total annual water use in similar large supermarkets net of cooling and irrigation use to fall between 1,200 and 1,700 kgal per year.

However, the five stores in the sample are not identical; they differ with respect to the total floor area and the volume of daily transactions. A "normalized" usage in gallons per year per square foot ranged among the five sites from 20.0 to 40.3 gallons. Therefore, if the midpoint of 30 gallons per square foot per year were used as a benchmark value, then the total indoor use for a 50,000 square-feet store would be 1,500 kgal per year.

A "tighter" range of values is obtained when the total indoor use is normalized by the number of transactions taking place in each store. The values of this benchmarking measure ranged from 1.08 to 1.40 gallons per transaction.

Table 6.1 Field studies benchmarks for supermarkets

Parameter/Location	Irvine Ranch	Los Angeles	Phoenix	San Diego	Santa Monica
INDOOR USE					
Kgal/year	1,531	1,685	1,215	1,315	1,370
Square feet of floor area	38,000	50,000	48,000	66,000	45,000
Gal./sf/year	40.3	33.7	25.3	20.0	30.4
Transactions/day	3,900	3,300	2,550	3,150	3,300
Gal./year/transaction/day	392	511	476	417	415
Gal./transaction	1.08	1.40	1.30	1.14	1.14
Gal./sf/daily transaction	0.010	0.010	0.010	0.006	0.009
COOLING USE					
Kgal/year	2,234	3,390	2,655	2,560	2,190
Gal./sf/year	58.8	67.8	55.3	38.8	48.7
Kgal/year/ton of cooling	11.17	16.95	13.28	9.85	9.13
Cooling Concentration Ratio	2.7	1.9	2.2	2.2	3.3
Kgal/year/ton @CR=2.0	14.07	16.06	14.49	10.85	12.73
Gal./ton/1000 sf/daily transaction	0.095	0.097	0.118	0.052	0.086
Gal./1000 sf/daily transaction	19.0	19.4	23.6	13.5	20.6
IRRIGATION USE					
Kgal/year	0*	0	286	0	751
Irrigated area, (sf)	0	0	10,640	0	54,000
Gal/sf/year	0	0	26.9	0	13.9
Inches of application per year	0	0	43.1	0	22.3
TOTAL USE					
Kgal/year	3,765	5,075	4,156	3,875	4,311
Gal./sf/year	99.1	101.5	107.6	58.7	79.1
Gal./transaction	2.64	4.21	4.47	3.37	3.58

*A zero value for irrigation use indicates that there is no landscape to irrigate at this site.

Both the number of transactions and the number of square feet of the floor area can also normalize total indoor water use. The obvious benchmark, as shown in Table 6.1, would be 0.010 gallons per daily transaction per square foot, with two smaller values (0.006 and 0.009) obtained for the stores in San Diego and Santa Monica, respectively.

Cooling use represented 51 to 67 percent of total use in the five stores. When normalized by the cooling capacity of the towers, the cooling use ranged from 9.13 to 16.06 kgal per ton of cooling capacity per year. A slightly tighter range was obtained when adjusting for the differences in concentration ratios (CR) of the re-circulating water and it ranged from 10.85 to 16.06 kgal per ton per year at CR=2.0. The adjustment was made using the following formula for calculating water savings that result from changing the concentration ratio:

$$\text{Savings (\%)} = (CR2-CR1)/(CR1(CR1-1)) \tag{6.1}$$

Finally, when adjusted by the implied cooling needs of each store in terms of the number of people present (as approximated by the number of transactions) and the volume of space to be cooled (approximated by floor area), the cooling usage ranged from 0.052 to 0.118 gallons per ton per 1000 square feet per daily transaction at the cooling concentration ratio of 2.0. When the installed capacity is omitted, a reasonable benchmark value appears to be approximately 20 gallons per 1000 square feet per daily transaction. The high value in Phoenix (23.6) suggests substantially higher cooling needs in that city due to a hotter climate as compared with the California sites.

The development of benchmark measures and values for landscape irrigation has received a fair degree of attention (Bennett and Hazinski, 1993). Typically, the benchmark measure is the "application rate" of irrigation water per growing season. Table 6.1 indicates that the two stores that had irrigation use applied 43.1 and 22.3 inches per year, respectively. The difference between the two sites is due to climate as well as to irrigation efficiency. Bennett and Hazinski suggest an agronometrically derived irrigation requirement for Phoenix of 47.1 inches/year and for sites in Southern California sites (including Santa Monica) of 22.1 inches per year. These rates represent the difference between annual evapotranspiration and annual rainfall and are not corrected for irrigation efficiency and effective rainfall.

Benchmarks from the Audit Data

The benchmark values derived from the direct measurement field studies data for five supermarkets may not be applicable to larger populations due to small sample size. However, they are based on accurate measurements of specific end uses and, therefore, are helpful in evaluating which benchmarking measures are most appropriate.

The audit data contained water use and related information for 33 grocery stores. Table 6.2 shows the values of several benchmarking measures for the stores in the sample, displayed in percentile range.

The results in Table 6.2 can be compared with the measurements obtained for the five stores used in the direct measurement field studies. The results in Table 6.2 are presented as 10th, 25th, 50th, 75th and 90th percentile values in the audit data. For example, the median (50th percentile) value of indoor use (net of the estimated use for cooling and irrigation by auditors) in the sample was 33.3 gallons per square foot per year (as compared to the range from 20 to 40.3 gallons and a weighted average of 28.8 gallons per square foot per year in the field studies data). Similarly, cooling water use per square foot ranged from 0 to 122 gallons per square foot per year (as compared to the 39 to 68 range for the field studies data).

Table 6.2 Audit data benchmarks for supermarkets*

	Supermarket Percentiles				
	10%	**25%**	**50%**	**75%**	**90%**
INDOOR USE					
Kgal per year	761.9	981.4	1135.5	1609.0	2292.5
Gal./sf/year/	17.3	23.6	33.3	45.9	63.6
Gal./transaction	1.1	1.5	1.7	2.1	3.9
COOLING USE					
Kgal per year	127.6	988.1	1,481.8	1775	2,785.9
Gal./sf/year	0	20.6	35.8	54.2	65.8
IRRIGATION USE					
Kgal/year	0	0	0	0	131.7
Gal./sf/year	10.0	24.9	37.0	43.2	48.3
Inches per year	16	40	52.3	69.2	77.5
TOTAL USE					
Kgal/year	2,215.6	2,404.8	2,600.1	3,528.3	4,077.8
Gal./sf/year	52.2	57.2	81.3	105.0	127.2
Gal./transaction	2.7	3.0	3.9	5.7	11.6

* Percentile values reflect independent distributions.

Benchmarks Derived from Statistical Models

The regression model for supermarkets permits estimation of water use in each establishment from audit data when special uses are excluded by setting the values of binary variables that designate their presence to zero. For example, water use in grocery stores net of that used by floral, seafood, water vending, and food preparation departments and net of outdoor irrigation can be calculated as:

$$Q\ (net\ indoor\ with\ cooling) = 4977.21 + 12.626\ (employees) + 0.020\ (floor\ area) \quad (6.2)$$

The predicted values can be used to calculate indoor (plus cooling) water use per square foot (or employee) and determine what would be the expected average value of that use.

Table 6.3 shows percentile ranges for predicted values of net indoor water use for the supermarkets and derives the benchmarking values based on the normalizing variables that were available in the audit data. The median rate of indoor (with cooling) use per square foot of floor area is 59.0 gallons per year. The median rate of water use for irrigation was 45.5 inches per year.

Table 6.3 Predicted benchmark values for supermarkets*

	Supermarket Percentiles				
	10%	**25%**	**50%**	**75%**	**90%**
INDOOR USE (W/COOLING)					
Kgal per year	2,154	2,230	2,334	2,477	2,545
Building area, (sf)	24,520	25,000	40,000	45,000	53,800
Gal./sf/year	46	52	59	85	89
Gal./sf/daily transaction	0.020	0.026	0.029	0.041	0.058
Gal./transaction	2.3	2.8	3.2	4.1	5.3
IRRIGATION USE					
Kgal per year	0	0	0	0	173
Inches per year	28.5	33.3	45.5	53.5	54.8
TOTAL WATER USE					
Kgal per year	2,317	2,496	2,767	3,211	3,462
Gallons per square foot per year	56	62	76	89	103
Gallons per transaction	2.8	3.1	4.1	5.2	5.9

* Percentile values reflect independent sampling distributions.

Office Buildings

Benchmark Usage Values from Field Studies Data

Total use in office buildings varied substantially because of the different sizes of buildings in the field studies. When normalized by the floor area, the usage ranged from 21 to 59.2 gallons per square foot per year with a weighted average of 39.1 gallons (see last row of Table 6.4). These high usage values and high variability are influenced by the presence of irrigation and cooling uses.

Table 6.4 Field studies benchmarks for office buildings

Parameter/Location	Irvine Ranch	Los Angeles	Phoenix	San Diego	Santa Monica
INDOOR USE					
kgal/year	562	4035	135	352	755
Building area (sf)	57,785	176,500	10,000	8,800	186,000
Number of employees	--	650	--	110	--
Gal./sf/year	9.7	22.9	13.50	40	4.1
Gal./employee/day		17.0		8.8	
COOLING USE					
kgal/year	0.0	6000	0.0	0.0	2250
Tons of cooling		518			560
kgal/year/ton of cooling		11.6			4.3
Gal./sf/year		34			12.1
IRRIGATION USE					
kgal/year	1,477	420	273	2	800
Irrigated area, (sf)	23,500	4,000	2,400	100	5,000
Gal./sf/year	62.9	105.00	113.75	20	160.00
Inches per year	100.8	168.4	182.5	385.0	256.7
Local ET less rainfall (inches/yr)	28.1	23.6	44.8	28.1	24.1
TOTAL USE					
kgal/year	2,039	10,455	406	374	3,903
Gal./sf/year	35.3	59.2	40.6	42.5	21

Indoor use (net of cooling and irrigation) ranged from about 4. to 38 gallons per square foot per year with a weighted average of 12.4 gallons. This wide range of values indicates that the floor area of an office building is not an appropriate normalizing factor. The number of employees and visitors would provide a better measure of size; however, this information was not available for all five sites. The usage per employee was 17 and 8 gallons per day in two buildings where the employment data were available.

Cooling use represented a major use in two office buildings using cooling towers. The usage rates were 34 and 12.1 gallons per square foot per year. Again, this is a wide range and offers little information about a possible benchmark value.

Irrigation use was present in all five sites and showed very high rates of water application ranging from 100.8 to 385 inches per year, several times more than the irrigation requirements of grass or other landscaping plants (i.e., 47.7 inches per year in Phoenix and 22.1 inches per year in Southern California).

Table 6.5 Benchmarking values from audit data for offices*

	Office Building Percentiles				
	10%	**25%**	**50%**	**75%**	**90%**
INDOOR USE					
kgal/year	113.6	516.5	1,895.4	3,576.6	6,247.3
Gal./sf/year	3.9	9.4	14.2	25.1	45.5
Gal./employee/day	5.7	9.4	13.3	22.8	58.0
COOLING USE†					
kgal/year	0	0	1,112.7	3,133.4	7,059.5
Gal./sf/year	0	0	5.3	15.1	30.4
IRRIGATION USE†					
kgal/year	0	2.6	710.6	2,950.9	4,288.7
Gal./sf/year	0	13.3	26.1	36.5	47.3
Inches/year	0	0.6	34.9	58.4	43.0
TOTAL USE					
kgal/year	1,320.6	2,780.9	5,050.5	8,005.5	16,468.6
Gal./sf/year	10.9	26.5	37.5	64.5	99.3

* Percentile values reflect independent sampling distributions.

† Zero values are the result of missing data.

Benchmarks from Audit Data

Table 6.5 shows the percentile distribution of water use rates in offices as derived directly from the audit data. The median value of indoor use is 14.2 gallons per square foot per year and 13.3 gallons per employee per day. These estimates compare well to the values obtained from the direct measurement field studies. The data reveals a median value of 5.3 gallons per employee per day for cooling use. Also, the median value of irrigation use is 26.1 gallons per square foot of irrigated area. Office buildings' total water use, on average, is 37.5 gallons per square foot per year (or 0.10 gal/sf/day).

Table 6.6 Predicted benchmark values for office buildings*

	Office Building Percentiles				
	10%	**25%**	**50%**	**75%**	**90%**
INDOOR USE					
kgal/year	1,255	1,913	2,925	4,817	6,718
Gal./sf/year	9.5	13.6	21.9	28.6	41.9
Gal./employee/day	14.8	15.8	19.2	30.9	94.7
COOLING USE					
kgal/year	2	6	1,113	1,503	2,557
IRRIGATION USE					
kgal/year	0	254	898	2,454	4,654
Inches/year	48	48	48	48	48
TOTAL USE					
kgal/year	2,403	3,572	5,796	8,446	10,970
Gal./sf/year	19.4	25.4	39	54.9	72.8

* Percentile values reflect independent sampling distributions.

Benchmarks from Statistical Models

Table 6.6 shows the distribution of model predictions for water use in offices. The results show a median value of indoor use of 21.9 gallons per square foot per day and 19.2 gallons per employee per day. The median value of cooling use is 1,113 kgal in a year. For irrigation use, the average usage is 898 kgal in a year. The data reveals a median value of 39 gallons per square foot of building area for yearly total water use (or 0.11 gal/sf/day).

Restaurants

Benchmark Usage Values from Field Studies Data

Table 6.7 shows a wide range of total water use in the five restaurants examined during the field studies, both in terms of total annual use at the establishment and in terms of usage per square foot of building area. The normalized usage ranged from 163 gallons per square foot per year in the Irvine Ranch restaurant to 731 gallons per square foot per year in the Phoenix restaurant. In terms of the seating capacity, the total usage ranged from 8.0 to 64.9 gal/seat/day. For comparison, a 1983 study reported average use of 24.2 gal/seat/day (Miller, J.E. and M.A. Miller 1983).

Indoor usage showed a slightly narrower range from 163 to 563 gallons per square foot per year with a weighted average of 289 gallons per square foot per year. The most consistent benchmarking measure is usage per employee per day which ranged from 40.3 to 84.1 gallons per employee per year, with a weighted average of 71.5 gallons per employee per year.

Cooling use was present in the restaurant in Phoenix and represented more than one-half of total use in the establishment. The Phoenix site also had a significant irrigation requirement with a very high application and evapotranspiration rates.

Benchmarks from Audit Data

Table 6.8 shows the percentile distribution of water use rates in restaurants as derived directly from the audit data. The results show a median value of indoor use of 145.6 gallons per employee per day and 32.5 gallons per seat per day. Median indoor use involves 306.1 gallons per square foot and 585.2 gallons per meal served. The median value for yearly total water use is 308.4 gallons per square foot of building area.

Table 6.7 Field studies benchmarks for restaurants

Parameter/Location	Irvine Ranch	Los Angeles	Phoenix	San Diego	Santa Monica
INSIDE USE					
kgal/year	735	3,070	1,390	1,120	676
Building area (sf)	4,500	9,800	4,825	--	1,200
Number of employees	50	100	50	--	25
Avg. meals served/day	750	800	700	190	540
Number of seats	253	200	149	216	73
Gal./sf/year	163.3	313.3	288.1		563.3
Gal./employee/day	40.3	84.1	76.2		74.1
Gal./meal served	2.7	10.5	5.4	16.1	3.4
Gal./seat/day	8.0	42.1	25.6	14.2	25.4
COOLING USE					
kgal/year	--	--	730	--	--
Tons of cooling	--	--	--	--	--
kgal/year/ton of cooling	--	--	--	--	--
Gal./sf/year	--	--	151.3	--	--
IRRIGATION USE					
kgal/year	0.0	55	1410	0.0	0.0
Irrigated area, (sf)	0.0	250	11,750	0.0	0.0
Gal./sf/year	0.0	220	120	0.0	0.0
Inches per year	0.0	352.9	192.5	0.0	0.0
TOTAL USE					
kgal/year	735	3,252	3,528	1,319	785
Gal./sf/year	163.3	331.8	731.2	--	654.2
Gal./employee/day	40.3	89.1	193.3	--	86.0
Gal./meal served	2.7	11.1	13.8	19.0	4.0
Gal./seat/day	8.0	44.5	64.9	16.7	29.5

Table 6.8 Audit data benchmarks for restaurants*

	Restaurant Percentiles				
	10%	25%	50%	75%	90%
INSIDE USE					
kgal/year	1,065	1,657.9	2,256.0	3,259.8	4,773.3
Gal./sf/year	110.0	163.0	306.1	473.7	767.6
Gal./employee/day	73.6	111.1	145.6	227.4	531.6
Gal./meal served	5.8	7.0	11.2	18.7	35.5
Gal./seat/day	19.5	24.9	32.5	46.9	73.8
IRRIGATION USE†					
kgal/year	0	0	0	71.1	228.59
Gal./sf/year	0	0	0	30.8	39.5
TOTAL USE					
kgal/year	1,157.0	1,717.5	2,457.9	3,298.3	4,773.3
Gal./sf/year	117.5	179.3	308.4	477.3	795.4
Gal./meal served	5.8	7.5	11.5	20.0	36.0
Gal./seat/day	19.9	25.0	37.4	49.4	74.1
Gal./employee/day	78.1	117.1	150.6	250.2	575.5

* Percentile values reflect independent sampling distributions.

† Zero values are the result of missing data.

Benchmarks from Statistical Models

Table 6.9 shows the distribution model predictions for water use in restaurants. Unlike other model predictions and the restaurant audit data, cooling and irrigation estimates are not separable from a base total use. The results show a median value of total water use of 175 gallons per employee per day and 34.7 gallons per seat per day. Other median values for total water use are 301 gallons per year per square foot of building area and 10.9 gallons for every meal served.

Table 6.9 Predicted benchmark values for restaurants*

	Restaurant Percentiles				
	10%	25%	50%	75%	90%
TOTAL USE					
Kgal/year	1,618	2,170	2,616	3,084	3,947
Base kgal/year†	1,636	2,061	2,427	3,010	3,444
Gal./sf/year	122	189	301	410	628
Gal./sf/year (with irrigated area)	74	130	227	379	571
Gal./meal served	8.0	9.2	10.9	13.8	19.8
Gal./seat/day	26.1	30.5	34.7	41.9	49.7
Gal./employee/day	93	122	175	238	388

* Percentile values reflect independent sampling distributions.

† The base total is the predicted annual total which assumes that none of the audited restaurants are either Chinese or fast food (by setting all Chinese and fast food indicators to zero). All calculations use this base total.

Hotels and Motels

Benchmark Values from Field Studies Data

Total water use differed among the five hotels by a factor of 3. The normalized use ranged from 98.4 gallons per day per room to 180.9 gallons per room per day, as shown in Table 6.10. After subtracting the cooling, irrigation and swimming pool uses, the remaining indoor use ranged only from 98.4 to 113.0 gallons per room per day with a weighted average of 106 gallons per room per day. Because of the small variability, the average use of approximately 38,000 gallons per room per year can be considered a benchmark indoor usage in a hotel.

Alternative benchmarking measures include average daily use per occupied room and average daily use per occupant. These measures indicate that a benchmark of approximately 120 gallons per occupied room per day or 60 gallons per occupant per day can be used for typical hotels. The hotel in Los Angeles was a high service hotel with additional water usage for its kitchen and banquet facilities.

Table 6.10 Field studies benchmarks for hotels

Parameter/Location	Irvine Ranch	Los Angeles	Phoenix	San Diego	Santa Monica
INDOOR USE					
Kgal/year	5,580	12,250	5,606	7,503	6,140
Number of rooms	148	297	140	209	168
Occupancy rate	0.9	0.7	0.8	0.9	0.9
Average guests per room	2	1.2	1.3	2	3
Gal./room/day	103.3	113	109.7	98.4	100.1
Gal./occupied room/day	114.8	152.7	146.3	109.3	117.8
Gal./occupant/day	57.4	127.3	112.5	54.6	39.3
COOLING USE					
Kgal/year		5,850			1,840
Tons of cooling		600			--
Kgal/year/ton of cooling		9.8			--
Gal./occupied room/day		72.9			35.3
IRRIGATION USE					
Kgal/year		1,410	3,239		245
Irrigated area, (sf)		31743	22,672		5510
Gal./sf/year		44.4	142.9		44.5
Inches per year		71.3	229.2		71.3
SWIMMING POOL USE					
Kgal/year	310		400		430.0
Surface area of pool, (sf)	800	375	800	225.0	320.0
Inches per year	621.7		802.1		2,155.7
TOTAL USE					
Kgal/year	5,887	19,499	9,245	7,503	8,657
Gal./room/day	109.0	179.9	180.9	98.4	141.2

The cooling use rates were 72.9 and 35.3 gallons per room per day in two hotels in which cooling use occurred. The irrigation use was substantial in two hotels, with application rates substantially exceeding the actual requirements of landscaping materials. Similarly, the use of water for swimming pools, while not a major use in the sampled hotels, showed rates of water loss much greater than evaporations rates, possibly indicating periodic draining and refilling of pools.

Benchmarks from Audit Data

Table 6.11 shows the percentile distribution of water use rates in hotels as derived from the audit data. The median value of indoor use is 72.6 gallons per square foot per year and 116.8 gallons per room per day. Median indoor use also involves 163.9 gallons per occupied room per day. The median value of irrigation use is 22.2 gallons per square foot per year. The average annual use is 90.5 gallons per square foot per year.

Table 6.11 Audit data benchmarks for hotels*

	Hotel Percentiles				
	10%	**25%**	**50%**	**75%**	**90%**
INDOOR USE					
Kgal/year	834.0	3,047.0	5,674.3	12,647.0	23,667.1
Gal./sf/year	17.4	48.8	72.6	131.8	206.5
Gal./room/day	55.0	85.1	116.8	145.4	187.9
Gal./occupied room/day	81.3	114.9	163.4	199.1	271.0
COOLING USE†					
Kgal/year	0	0	0	1,519.8	5,824.4
Gal./occupied room/day	0	0	0	19.7	58.3
Gal./sf/year	0	0	0	4.7	16.9
IRRIGATION USE†					
kgal/year	0	0	271.5	1,169.5	2,854.7
Gal./sf/year	0	11.9	22.2	44.9	60.1
TOTAL USE					
Kgal/year	1,334.4	3,372.0	7,287.0	17,394.7	2,9509.8
Gal./sf/year	11.7	55.4	90.5	147.8	240.0
Gal./room/day	64.3	96.5	146.3	173.9	232.4

* Percentile values reflect independent sampling distributions.
† Zero values are the result of missing data.

Benchmarks from Statistical Models

Table 6.12 shows the distribution of model predictions for water use in hotels. The results show a median indoor use of 206.7 gallons per occupied room per day with the median irrigation use being 27.2 inches per year. Total water use shows a median value of 74 gallons per square foot per year, or 0.2 gal./sf/day. The estimates of this measure reported in the Johns Hopkins study were 0.3 gal./sf/day for hotels and 0.2 gal./sf/day for motels (see Table 2.14 in Chapter 2) (Wolff et al. 1966).

Table 6.12 Predicted benchmark values for hotels*

	Hotel Percentiles				
	10%	25%	50%	75%	90%
INDOOR USE (WITH COOLING)					
kgal/year	3,144	4,051	7,018	18,446	28,230
Gal./occupied room/day	107.1	136.2	206.7	251.0	282.7
IRRIGATION USE					
kgal/year	0	27	179	986	2,650
Inches per year	9	15.8	27.2	48	67.2
TOTAL USE					
kgal/year	3,222	4,237	8,008	20,365	34,958
Gal./sf/year	27	48	74	156	236
Gal./occupied room/day	117.1	147.8	221.1	272.4	309.2

* Percentile values reflect independent sampling distributions.

Schools

Benchmark Values from Field Studies Data

Table 6.13 shows the benchmark usage values from the field studies data for high schools. The direct measurement field studies look only at high schools while the audit data contained information on a range from elementary schools through colleges. A weighted per student use in high schools was 22.2 gallons per calendar day. Indoor use per student, net of the observed leaks ranged from 1.4 to 3.5 gallons per school day with a weighted average of 2.8 gallons. For comparison, the Johns Hopkins study reported average use per student of 3.8 gallons per day in elementary schools and 8.0 gallons per day in high schools (Wolff et al. 1966). Total irrigation water use ranged from 6,074 to 25,058 kgal in a year. Irrigation use per square foot of irrigated area ranged from 15.4 to 36.5 gallons per year.

Table 6.13 Field studies benchmarks for high schools.

Parameter/Location	Irvine Ranch	Los Angeles	Phoenix	Santa Monica
INDOOR USE				
kgal/year	1,494	4,900	2,629	2,268
Leaks: kgal/year	805	350	1,371	344
Building area, (sf)	224,652	253,357	325,000	220,000
Number of students	2,640	3,850	2,186	3,065
Annual operating days	180	340	180	340
Gal./sf/year	7	19	8	10
Gal./student/calendar day	1.6	3.5	3.3	2.0
Gal./student/school day	3.1	3.7	6.7	2.2
Gal./student/school day w/o leaks	1.4	3.5	3.2	1.8
COOLING USE				
kgal/year			7500	
Tons of cooling				
kgal/year /ton of cooling				
Gallons/occupied room/year			23.1	
IRRIGATION USE				
kgal/year	22,055	21,121	25,058	6,074
Irrigated area, (sf)	1,300,000	579,125	784,000	395,000
Gal./sf/year	17.0	36.5	32.0	15.4
Inches per year	27.2	58.5	51.3	24.7
SWIMMING POOL USE				
kgal/year	195			95.0
Surface are of pool, (sf)	5760			11250.0
Inches per year	54.3			13.5
TOTAL USE				
kgal/year	24,549	26,371	36,558	8,781
Gal./sf/year	109	104	112	40
Gal./student/calendar day	25.5	18.8	45.8	7.8

Benchmarks from Audit Data

Table 6.14 shows the percentile distribution of water use rates in schools as derived directly from the audit data. The results show a median value of indoor use of 6.4 gallons per student per calendar day and 11.5 gallons per student per school day. Median indoor use also involves 24.4 gallons per square foot in a year. The results show a median value of irrigation use of 17.1 gallons per square foot of irrigated area. The median value for yearly total water use is 111.7 gallons per square foot of building area and 21.8 gallons per student per day. The unit water use for swimming pools varies between the two sites that have pools by a factor of 4. The most likely explanation for this is that the pool in Irvine was outdoors while that in Santa Monica was indoors.

Table 6.14 Audit data benchmarks for schools*

	School Percentiles				
	10%	**25%**	**50%**	**75%**	**90%**
INDOOR USE (with cooling)					
kgal/year	950.1	1,384.2	2,086.9	4,406.8	8,945.2
Gal./sf/year	9.1	16.3	24.4	38.4	57.0
Gal./student/calendar day	3.3	4.4	6.4	8.7	13.7
Gal./student/school day	5.9	8.1	11.5	16.2	24.3
IRRIGATION USE					
kgal/year	7.5	1,456.7	4,479.8	10,703.9	180,39.5
Gal./sf/year	9.1	13.7	17.1	22.2	27.6
TOTAL USE					
kgal/year	2,426.2	4,189.2	6,970.6	14,866.9	25,147.3
Gal./sf/year	24.1	59.5	111.7	162.9	271.9
Gal./student/calendar day	8.4	14.2	21.8	31.0	44.2

* Percentile values reflect independent sampling distributions.

Benchmarks from Statistical Models

Table 6.15 shows the distribution of model predictions for water use in schools. The results show a median value of indoor use of 18.5 gallons per student per school day and 132.5

gallons per employee per calendar day. In addition, the data revealed a median value of indoor use of 139,707 gallons per square foot of building area per year. The median value of irrigation use is 4,014 kgal per year. The median value of total water use is 83 gallons per square foot of building area per year.

Table 6.15 Predicted benchmark values for schools*

	School Percentiles				
	10%	**25%**	**50%**	**75%**	**90%**
INDOOR USE					
kgal/year	1,484	2,580	3,507	5,584	8,067
Gal./employee/calendar day	85.7	107.0	132.5	174.2	222.5
Gal./student/school day	10.3	14.8	18.5	23.7	33.6
Gal./student/calendar day	5.0	8.1	9.7	12.7	19.0
COOLING USE†					
kgal/year	0	0	0	0	1,120
IRRIGATION USE					
kgal/year	759	1,412	4,014	8,028	13,380
SWIMMING POOL USE†					
kgal/year	0	0	0	0	2,095
TOTAL USE					
kgal/year	3,552	4,913	7,529	13,900	22,672
Gal./sf/year	21	40	83	146	176
Gal./student/calendar day	11.9	17.2	24.1	30.2	40.4

* Percentile values reflect independent sampling distributions.
† Zero values are the result of missing data.

EFFICIENCY BENCHMARKS

The statistical analysis of establishment level data for the five selected categories of CI urban water users permitted estimation of models for predicting total water use in establishments as a function of their size, magnitude of operations, specific type of establishment within a broad category, and presence of specific end uses.

The audit data and the field studies data were analyzed to determine the benchmarks of average and efficient rates of water use for each category of establishments. The derived values were compared with predictions derived from the statistical models. The comparison of results from all three sources allowed the project team to derive expected average rates of water use for various purposes as well as approximate values of efficient use.

Below, efficiency benchmarks are selected as the 25th percentile value for each efficiency measure. This value does not constitute an absolute measure of efficiency; instead, it represents an achievable low rate of use as evidenced by one-fourth of the sample establishments showing usage rates at or below the selected value. The results of these comparisons are presented in the following sections.

Restaurants

Table 6.16 shows the comparison data for restaurants. The data suggests that an efficient restaurant would use approximately 130 to 331 gallons per square foot of building area of water in a year, or 6 to 9 gallons of water per meal served. Furthermore, total water use for an efficient restaurant would fall within a range of use of 20 to 31 gallons per seat per day and 86 to 122 gallons per employee per day. The variability of these ranges is similar except for the values representing usage per square foot. In terms of the "tightness" of the range, the rate of use of gallons per meal served seems to provide the best benchmark of 11 gallons on average and 6 to 9 gallons in the 25^{th} percentile benchmark. A more precise benchmark for restaurants would be a value based on inside water use (net of cooling and irrigation). The inside use ranged from 2.7 to 16.1 gallons per meal in the field study data.

Table 6.16 Efficiency benchmarks for restaurants

End Use/Benchmark Measure	Data Source	N	Range	Median (Weighted Average)	25th Percentile Efficiency Benchmark
TOTAL USE					
	FS	5	163.3 - 731.2	493.0	331
Gal./sf/year	AD	85	22.2 – 1,537	310.8	179
	MD	78	39.9 – 1,801	300.6	130
	FS	5	2.7 – 19.0	11.1	6
Gal./meal served	AD	85	1.4 – 150.4	11.5	8
	MD	78	4.9 – 43.4	10.9	9
	FS	5	8.0 – 64.9	29.5	20
Gal./seat/day	AD	85	15.5 – 82.7	37.4	25
	MD	78	18.4 – 77.9	34.7	31
	FS	5	40.3 – 193.3	87.6	86
Gal./employee/day	AD	85	26.6 – 1,380	150.6	117
	MD	78	55.7 – 1,034	175.0	122

Note: FS-Field Study Data; AD-Audit Data; MD-Modeled Audit Data

Hotels and Motels

Table 6.17 shows the comparison of benchmark values for hotels and motels. The data suggests that an efficient hotel or motel would use about 110 to 115 gallons per day per occupied room for indoor purposes (while excluding the value of 60 gal/day from the modeled audit data). Concerning cooling use, an efficient hotel or motel would use around 7,400 to 41,600 gallons per occupied room in a year. Efficient irrigation use would involve 16 to 50 inches per year depending on the local weather conditions and the type of landscaping material. An efficient hotel's total water use should fall within a range from 108 to 148 gallons per occupied room per day.

Table 6.17 Efficiency benchmarks for hotels and motels

End Use/Benchmark Measure	Data Source	N	Range	Median (Weighted Average)	25th Percentile Efficiency Benchmark
INDOOR USE					
	FS	5	109.3 - 152.7	117.8	110
Gal./day/occupied room	AD	93	58.0 - 1326	164	115
	MD	92	60.0 - 106.7	106.7	60†
COOLING USE*					
	FS	5	12,885 – 26,618	21,209	20,000
Gal./year/occupied room	AD	93	1,825 – 158,487	14,609	7,400
	MD	92	36,945 – 87,501	44,933	41,600
IRRIGATION USE*					
	FS	5	71.3 - 229.2	131	30 – 50
Inches per year	AD	83	3.4 - 360	42.5	26
	MD	79	3.8 - 260.3	27.2	16
TOTAL WATER USE					
	FS	5	98 – 181	141	109
Gal./day/occupied room	AD	93	40 – 5656	149	108
	MD	92	78 - 1849	221	148

Note: FS-Field Study Data; AD-Audit Data; MD-Modeled Audit Data
* Appropriate benchmarks will depend upon local climate.
† The constant value is derived from model coefficients.

Office Buildings

Table 6.18 shows the comparable benchmarking data for office buildings. The data suggests that an efficient office building would use for indoor purposes approximately 9 to 15 gallons per square foot of building area per year, or 9 to 16 gallons per employee per day. Concerning cooling use, an efficient office building would use around 9 to 22 gallons per square foot per day. Efficient irrigation use would involve 26-50 inches per year depending on the local weather conditions and the type of landscaping material. An efficient office building's total water use (including irrigation and cooling) should range from 26 to 35 gallons per square foot per year, nearly two times more than the inside usage rate.

Table 6.18 Efficiency benchmarks for office buildings

End Use/Benchmark Measure	Data Source	N	Range	Median (Weighted Average)	25th Percentile Efficiency Benchmark
INDOOR USE					
	FS	5	4.1 - 37.5	13.5	10
Gal./sf/year	AD	72	2.4 - 965	14.2	9
	MD	49	1.9 - 92.9	21.9	15
	FS	5	8.2 - 17.0	15.7	12
Gal./employee/day	AD	69	3.6 - 3635	13.3	9
	MD	49	11.8 - 3041	19.2	16
COOLING USE*					
	FS	5	12.4 - 34.0	22.6	22
Gal./sf/year	AD	44	3.7 - 51.6	15.0	12
	MD	46	8.5 - 8.7	8.5	8.5†
IRRIGATION USE*					
	FS	5	101 - 385	182.5	30 – 50
Inches per year	AD	57	0 - 588	41.9	26
	MD	42	Only 48	48.0	48†
TOTAL WATER USE					
	FS	5	21.0 - 59.2	40.6	35
Gal./sf/year	AD	72	7.4 - 996	37.5	26
	MD	49	8.7 - 167.9	39.0	27

Note: FS-Field Studies Data; AD-Audit Data; MD-Modeled Audit Data
* Appropriate benchmarks will depend upon local climate.
† The constant value is derived from model coefficients.

Supermarkets

Table 6.19 shows the comparable benchmarking data for food stores. The data suggest that an efficient supermarket would use between 52 to 64 gallons per square foot of building area in a year. Also, an efficient supermarket would use approximately 0.02 to 0.03 gallons per square foot per daily transaction. Concerning irrigation use, an efficient supermarket would use about 30 to 50 inches per year depending on the local weather conditions and the type of landscaping material. An efficient supermarket's total water use would range from 57 to 80 gallons per square foot of building area and is approximately 3 gallons per transaction.

Table 6.19 Efficiency benchmarks for supermarkets

End Use/Benchmark Measure	Data Source	N	Range	Median (Weighted Average)	25th Percentile Efficiency Benchmark
INDOOR USE (WITH COOLING)*					
	FS	5	58.7 - 101.5	80.6	64
Gal./sf/year	AD	33	40.6 - 258.9	77.3	57
	MD	33	31.2 - 109.0	58.8	52
	FS	5	3.1 - 4.4	3.7	3.2
Gal./transaction	AD	33	0.6 - 14.8	3.9	3
	MD	33	0.6 - 5.7	3.2	2.8
	FS	5	0.02 - 0.03	0.03	0.02
Gal./sf/daily transaction	AD	33	0.005 – 0.2	0.04	0.03
	MD	33	0.005 - 0.08	0.03	0.03
IRRIGATION USE*					
	FS	5	22.3 - 43.1	25.7	30 – 50
Inches per year	AD	5	40.0 - 83.0	64.3	40†
	MD	5	25.3 – 55.6	45.5	33†
TOTAL USE					
	FS	5	58.7 – 107.6	99.1	80
Gal./sf/year	AD	33	40.6 - 258.9	81.3	57
	MD	33	33.1 - 124.8	75.6	62
	FS	5	2.6 - 4.5	3.6	3
Gal./transaction	AD	33	0.6 - 14.8	4.2	3
	MD	33	0.6 - 7.3	4.1	3

Note: FS-Field Study Data; AD-Audit Data; MD-Modeled Audit Data
* Appropriate benchmarks will depend upon local climate.
† There are only five observations for irrigation use in the grocery audit data.

Schools

Table 6.20 shows the comparison data for schools. Recall that the field study data comes exclusively from high schools while the audit data includes information from schools ranging from elementary to college level. The data suggests that an efficient school would use about 8 to 16 gallons per square foot per year for indoor use. Also, an efficient school would use between 3 to 15 gallons per school day per student for indoor use. Concerning cooling use, an efficient school would use around 8 to 20 gallons per square foot per year. Efficient irrigation use would involve 22 to 50 inches per year depending on the local weather conditions and the type of landscaping material. An efficient school's total water use should range from 40 to 93 gallons per square foot per year.

Table 6.20 Efficiency benchmarks for schools

End Use/Benchmark Measure	Data Source	N	Range	Median (Weighted Average)	25th Percentile Efficiency Benchmark
INDOOR USE					
	FS	4	8.0 - 19.0	9.0	8
Gal./sf/year	AD*	138	4.6 - 433.8	24.4	16
	MD	127	4.0 - 238.8	34.7	16
	FS	4	2.2 - 6.7	3.4	3
Gal./student/school day	AD*	137	4.0 - 142.2	11.5	4
	MD	125	2.3 – 51.2	18.5	15
COOLING USE‡					
	FS	4	Only 23.1	23.1	20
Gal./sf/year	AD				
	MD	125	8 - 30.7	8.0	8†
IRRIGATION USE‡					
	FS	4	24.7 - 58.5	39.1	30 – 50
Inches per year	AD	128	8.6 - 197.9	28.0	23.5
	MD	125	Only 21.5	21.5	21.5†
TOTAL WATER USE					
	FS	4	40 - 112	106.5	93
Gal./sf/year	AD	138	9.1 - 580.5	111.7	60
	MD	125	6.1 - 509.4	83.0	40

Note: FS-Field Study Data; AD-Audit Data; MD-Modeled Audit Data

* Indoor use will also include cooling use.

† The constant value is derived from model coefficients.

‡ Appropriate benchmarks will depend upon local climate.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

GENERAL CONCLUSIONS

CI Classifications and Data

The systems of classifying CI customers by water utilities are generally inadequate and frustrate efforts to compare water use for individual categories among cities. This problem exists not only in how CI customers are categorized, but over the whole issue of customer classification. First, there is no common nomenclature for classification of water customers. Customers are grouped into categories, sectors, classes, sub-classes, groups, etc; and the meaning of these terms varies from system to system. Next there is little or no agreement on how to group customers. Some utilities group all housing into a general residential category, and others split out multi-family, mobile homes, town homes etc into separate groups. Not all utilities include the same types of customers in the general CI sector and within the sector there is a wide divergence of how categories are defined, and only a few categories are common across many utilities. These include the categories selected for analysis in this study (hotels/motels, schools, restaurants, supermarkets, and office buildings) and other easily recognizable types of businesses, such as laundromats, car washes and others. Many other categorizations are specific to each utility and cannot be generalized. Also, a significant percentage of CI accounts do not fall into these categories and remain within the generic category of "other CI users." Thus, a significant recommendation of this study is to analyze and develop a standard customer classification scheme for all municipal water users. Such a classification will facilitate both demand planning and conservation evaluation activities.

Availability of Water Usage Benchmarks

Because the system of classifying customers is not standardized, it is impossible to develop benchmarks from billing records of water utilities for comparing water usage rates for the same categories of customers. Other obstacles to developing meaningful benchmarks of CI water use from billing records include:

- The distribution of CI customers by size is usually skewed with a small number of customers accounting for a majority of water use. This characteristic makes the average use of water per customer within a CI category very sensitive to the degree to which water use is concentrated within top accounts. Under this circumstance, the mean use per customer is not a reliable measure of water use. It can vary in time as the concentration of usage shifts and it can differ between cities with different degrees of concentration of use.
- The most appropriate variables for normalizing water use depend on the type of CI category and often cannot be easily measured. The only normalizing variable that is generally available to all utilities is the number of active accounts within a CI category. Another variable, the number of employees, can be obtained from government statistics but it is usually only available in an aggregate form. The employment data for individual establishments are usually confidential and imprecise. Other measures of size such as the number of meals served in a restaurant or the square footage of a retail store cannot be obtained from secondary sources and may require on-site data acquisition.
- In some categories of CI customers, demand is concentrated in one or two end uses. In order to develop benchmarks, both the size of the establishment and characteristics of the main end uses have to be known. Establishments with significant water use for landscape irrigation or cooling fall into this category.
- Irrigation use is separated for CI customers in a few utilities and embedded in CI use in others.

Identification of Conservation Potential

Billing records can be used for identifying the potential for water conservation among CI customers for a given water utility based on such characteristics of water use as:

- Degree of homogeneity of water use types (or composition of end uses) within a given CI category
- Inter- and intra-class variability of per account water use
- Total water use by category relative to the CI sector use

- Number of customers within category
- Presence of seasonal water use

Categories of CI users with high cross-sectional variability of usage rates and/or variability of usage rates throughout the year are likely candidates for conservation programs. Another important consideration is the number of customers within the category that have to be approached during program implementation. Categories with fewer users that account for a significant percentage of total water are likely to be better conservation targets than categories with a large number of customers.

Conservation Experience

The information on the opportunities for water conservation described in Appendix F can be summarized in terms the following findings and implications for the design and implementation of CI conservation programs:

- Some large-water-using categories have been ignored for water audits. Water audit programs need to include warehouses, correctional facilities, military bases, utility systems, and passenger terminals.
- Potential savings are in the 15 to 50 percent range, with 15 to 35 percent being typical. In addition, typical payback periods that have been experienced range between one and four years.
- Many ICI water users do not need to use potable water in all applications. Each customer and water use should be examined to determine if water of less-than-drinking-quality can be used or recycled on-site, or if reclaimed effluent could feasibly be used.
- Discussion of the successes and failures of other programs can provide insight. Cooperation between water, wastewater providers, and energy utilities is essential to demand management programs.
- Although nonresidential audits are becoming a more frequently employed conservation measure, documentation of programs are often not readily available.

In general, water conservation programs targeted at nonresidential customers are rarely well documented and evaluated. Many available documents lack direct information for generalizing water savings. There is a need for more information on program costs, implementation conditions, and measurement of savings.

CONCLUSIONS FROM DIRECT MEASUREMENT FIELD STUDIES

The direct measurement field studies portion of this study attempted to determine how data logging and flow trace analysis technique used in the Residential End Uses of Water Study (REUWS) should be applied to CI customers. It was understood that the flow patterns of CI customers are much more complex than those of residential customers, but it was thought that the flow trace analysis process could yield data from CI customers that might be possible to disaggregate to some extent. These data coupled with limited on-site audit information could yield considerably more information about water use patterns in the CI sector without requiring as much detailed investigation as a traditional audit.

In general, the smaller the meter, the better resolution can be obtained from flow trace analysis. In sites with 2" or smaller meters individual events such as toilets, showers, faucet use, dishwashers could be observed. As meters become larger water use becomes more continuous, which makes is more difficult to identify and classify individual water use "events". Furthermore, larger meters give fewer magnetic pulses per gallon, which makes it impossible to identify any event that uses less than the resolution of the meter. For example, in a meter that gives only 1 pulse per 8 gallons of water, any event which uses less than 8 gallons will be automatically lumped with other use.

However, even on larger meters, it is normally quite easy to distinguish large uses for irrigation, indoor uses, and continuous flows for cooling and leakage. This allows a time series to be developed for each category and makes it possible to track changes in each separately. For example, in a supermarket one could construct data sets of indoor use and exclude irrigation and cooling uses. Changes in indoor uses could be tracked after an indoor efficiency program was implemented. Because only indoor uses were being measured, it would be much easier to detect changes when the large and variable uses for cooling and irrigation were excluded.

The results from this study showed that flow trace analysis is a valuable tool for conducting water audits and evaluating the impacts of conservation programs on CI customers, which can be employed on a wide range of customer types and sizes. The process can identify leakage, continuous uses, and irrigation on even very large sites. It can also identify large blocks of process use water at sites, which can be identified during the audit process. At smaller sites individual fixtures and pieces of equipment can be identified. For analysis of conservation impacts, flow trace analysis provides time series data with smaller variability by eliminating the mixing of uses. This reduction makes it easier to detect changes in use patterns that might result from conservation programs or retrofits.

Conclusions Regarding Conservation Potential in Study Categories

The experience gained during the field studies has made it possible to make some general conclusions about water conservation opportunities in the various categories of CI customers.

Cooling Towers

The water use by cooling towers is so significant that separate discussions are warranted which would apply to any site using an evaporative cooling system. Evaporative cooling is used in most large air conditioning and refrigeration systems as a way of passing heat from the refrigerant condensers to the atmosphere. These systems were found in all of the supermarkets, which have intense refrigeration loads, and in larger offices, hotels and high schools. Where present, evaporative coolers were either the first or second water user on the site (usually behind only irrigation.)

Only two of the five offices in this study group had evaporative coolers, so it is impossible to generalize, but the fact that the building with the highest level of control and treatment on the cooling system used one third as much water per square foot as the other, more standard system, indicates that substantial savings could be obtained by improving the control and treatment of cooling towers. The key, is to operate them at higher levels of TDS in the water circulating in the tower. This increases the cycles of concentration and decreases the amount of make-up water required. In order to operate at higher TDS levels, however, requires better treatment of the water. This can include filtration, disinfection and pH control. All of these techniques were used at the Santa Monica office. In addition, operation at higher TDS levels requires better and more accurate monitoring devices. Ideally, meters on the make-up and blow down lines would be helpful, plus TDS and pH meters on the circulation water.

An honorable mention should go to the cooling system at the San Diego office site. This is a fairly high tech system which stores chilled water in insulated tanks in the basement. The cooling system can then operate at a constant rate, and does not require any evaporation for heat rejection. The water system is totally closed loop and the condenser is also cooled with a fan unit. Neither system relies upon evaporation. During peak demand periods the excess load on the condenser is made up by cool water from the basement tanks, and during off peak times this water is cooled off with the excess capacity of the air cooled chiller.

Office Buildings

As shown by the disaggregation studies, irrigation practices in office buildings tend to be extravagant. In four of the five buildings studied applications were between 3 and 8 times the required amounts. Significant savings in irrigation use should be possible in offices without sacrificing any landscape quality.

Indoor use in offices tends to be dominated by typical domestic uses: mainly sanitation, and cleaning. This makes offices prime candidates for high efficiency plumbing fixtures and appliances. The full range of devices from waterless urinals and sensor activated faucets should be investigated.

Where cooling towers are present, they are certainly going to use large amounts of water, and should be monitored carefully.

Restaurants

In the absence of cooling towers and irrigation the major water users in most restaurants are faucets, dishwashers, and ice machines. Leakage, where present, can dominate other uses. In our study, the two sites with significant leakage were impossible to disaggregate into individual events. Some promising ways to water conserve water in restaurants is first to eliminate leakage. Recirculation systems can be installed on the dishwashers so that final rinse water can be used for washing the next load. Installing hands free faucet controllers will eliminate the temptation to leave faucets running continuously. Garbage disposals can be replaced with garbage strainers that use a stream of recirculation water to rinse the garbage; the washed residue is then sent out with the trash. Ice machines that make cubes use significant amounts of water for rinsing. These can be replaced with air cooled machines which make flake ice. These air cooled machines do not require rinsing and use far less water, but offer tradeoffs in terms of the cost of operation for electricity and heating load. Since toilet and urinal use is also significant at restaurants efforts should be made to install high efficiency devices. This can be very effective since normally there are relatively few fixtures which are used heavily, so a single replacement can effect a large number of uses.

Supermarkets

The major use in supermarkets is cooling water, which accounts for from one-half to two thirds of total indoor use. Clearly, conservation efforts should be focused on improving the operation of these devices. Behind cooling towers, come the many faucets that are used for everything from washing produce to making food and cleaning floors. Many of these faucets are left running for long periods of time, especially in kitchens and food court operations. Hands free controllers for these faucets could dramatically reduce water use. There was a surprising amount of toilet and urinal use in the supermarkets that could be identified from the flow traces. Consequently, efforts at installing high efficiency fixtures should be effective.

Hotels

One-half to three-quarters of indoor use at the hotels in this study was for toilets, faucets and showers. Naturally, these should be the first target of a hotel water conservation program. Almost all ice machines were cube type, so replacement of these with flake machines could be explored to save water. Leakage was found at significant levels in three of the five hotels studied. The flow traces revealed that a high percentage of these leaks were due to stuck flappers in toilets. Cases where a single toilet would run for more than a day were found, and toilet runs of several hours were not uncommon. Better toilet flappers would save large amounts of water in these facilities. Other leaks were due to irrigation valves, faucets and other small devices. Laundries at hotels are major water users. High efficiency machines and machines which recycle final rinse water for the wash cycle of the next load are logical items to consider for conservation at hotels.

High Schools

Most of the variation in water use at high schools was a function of the amount of irrigation at the site and whether or not evaporative cooling was taking place. The indoor use does not vary that much on a per square foot basis. Irrigation at the high schools was more carefully controlled than that at the offices as measured by comparing the actual application rates to the theoretical requirements. All of the schools were irrigating either near or below the ET level. In the school with the highest water use, in Phoenix, over 80 percent of the water was being used for irrigation of playing fields and operation of the cooling tower. The irrigation application was below the ET level for Phoenix, but the cooling tower was operating at a concentration ratio of only 2.3, which could be have been increased to 3 or 4. Most of indoor use at these schools was for typical domestic uses, and on average accounted for 25 percent of total use.

MODELING CONCLUSIONS

Statistical Models

Based upon the opinions of an expert panel, the conditional demand analysis (CDA) methodology was determined to be a good candidate for decomposing water use in CI establishments into water used through various sanitary, cooling, outdoor, and other end uses. However, the practical limitations on sample size and missing variable data (from water audits) precluded a comprehensive standard application of this promising modeling technique. Future research in applying the CDA technique is recommended, although such an effort will require a targeted mail or field survey of a large sample of CI establishments to overcome the practical data limitations uncovered in this study.

The statistical analysis of establishment level data for the selected five categories of CI urban water users permitted estimation of models for predicting total water use as a function of several explanatory variables including:

- Establishment size and physical property characteristics
- Magnitude of operations, including levels of employment and customer traffic,
- Specific type of services within a broad CI category, and
- A mix of specific end uses of water in the establishment

The specification of the "best" models depended on the type of establishment, but in all five establishment types the estimated equations allowed for only a limited disaggregation of total water use into its constituent end uses.

The models that were estimated were capable of explaining a substantial amount of variance in water use among the establishments in the sample, and are helpful aids not only for predicting CI use, but as indicated in the next chapter, are helpful for establishing efficiency benchmarks for CI use.

Water Efficiency Benchmarks

The statistical analysis of establishment level data for the selected five categories of CI urban water users permitted estimation of models for predicting total water use in establishments as a function of their size, magnitude of operation, specific type of establishment within a broad category, and presence of specific end uses.

The audit data and the field studies data were analyzed to determine the benchmarks of average and efficient rates of water use for each category of establishments. The derived values were compared to predictions derived from the statistical models. The comparison of results from all three sources allowed the project team to derive expected average rates of water use for various purposes as well as approximate values of efficient use.

The efficiency benchmark was selected as the 25th percentile value for each efficiency measure. This value does not constitute an absolute measure of efficiency; instead, it represents an achievable low rate of use as evidenced by one-fourth of the sample establishments showing usage rates at or below the selected value.

Restaurants

The benchmarking analysis suggests that an efficient restaurant would use approximately:

- 130 to 331 gallons per square foot of building area of water in a year,
- 6 to 9 gallons of water per meal served,
- 20 to 31 gallons per seat per day,
- 86 to 122 gallons per employee per day.

Please note that benchmarking values for restaurants is for total use inclusive of cooling and irrigation.

Hotels/Motels

The benchmarking analysis suggests that an efficient hotel or motel would use approximately:

- 60 to 115 gallons per day per occupied room for indoor purposes,
- 16 to 50 inches per year for irrigation use (depending on the local weather conditions and the type of landscaping material),
- 39 to 54 kgal. total per year per occupied room.

Office Buildings

The benchmarking analysis suggests that an efficient office building would use approximately:

- 9 to 15 gallons per square foot of building area per year for indoor purposes,

- 9 to 16 gallons per employee per day for indoor purposes,
- 8.5 to 22 gallons per square foot per year for cooling,
- 26 to 50 inches per year for irrigation use (depending on the local weather conditions and the type of landscaping material),
- 26 to 35 gallons total use per square foot per year.

Supermarkets

The benchmarking analysis suggests that an efficient supermarket would use approximately:

- 52 to 64 gallons per square foot of building area in a year for indoor use,
- 0.02 to 0.03 gallons indoor use per square foot per daily transaction,
- 30 to 50 inches per year for irrigation use (depending on the local weather conditions and the type of landscaping material),
- 57 to 80 gallons total use per square foot of building area per year,
- 3 gallons total use per transaction.

Schools

The benchmarking analysis suggests that an efficient school would use approximately:

- 8 to 16 gallons per square foot per year for indoor use,
- 3 to 15 gallons per school day per student for indoor use,
- 8 to 20 gallons per square foot per year for cooling use,
- 22 to 50 inches per year for irrigation use (depending on the local weather conditions and the type of landscaping material),
- 40 to 93 gallons total use per square foot per year.

RECOMMENDATIONS

The results of this study and the insights gained through the field investigations and data modeling and analysis support the following recommendations for the management of water demands in the commercial and institutional sector of urban water users.

1. A standardized classification scheme of all municipal water customers, including CI customers, should be developed by water industry to facilitate both demand planning and evaluation of conservation programs. The existing classification systems are generally inadequate for comparing water use of similar customer categories between different water providers.

2. Category-wide benchmarks of CI water use cannot be developed on the basis of average daily or annual water use per active account (or customer) within a CI category due to the differences in size of establishments that comprise the category. Meaningful aggregate benchmarks can be developed by collecting additional aggregate data on the size of the CI activity represented by a category. The aggregate measures of size could include the combined square footage of all buildings in the category, total category employment, school enrollment, seating capacity (in restaurants), number of hotel rooms or other aggregate measures of business size in the service area. Benchmark values should be developed by dividing the total category water use by the scaling measure.

3. It is recommended that water agencies institute a routine collection of supplemental data from their CI customers on the size of their business. Only the relevant information should be collected to minimize the burden on the individual customers. The common measures of business activity (and size) such as the number of employees, square footage of all buildings or number of transactions per unit time should be adequate for benchmarking purposes. Establishment-level benchmarks can be very useful in assessing the conservation potential of individual CI customers. However, the development of meaningful benchmarking measures would require good information on both the establishment's water use and the identification of establishment type and size.

Opportunities may exist for partnering with other utilities and agencies to obtain this supplemental data. Many electric and gas utilities and taxing authorities maintain extensive databases on CI customers including square footage, number of employees, sales tax generated, etc. Water agencies should make use of existing data resources whenever possible and should not bother customers with information requests unless accurate establishment level data is not available.

4. Utilities should consider developing efficiency benchmarks for their larger CI end uses. Maintaining this tool may require additional data collection or partnering with other utilities and agencies, however, the net utility cost should be considerably less than blanketing all CI customers for detailed conservation assistance. Whether it be for informing customers of their relative rankings, providing technical assistance, or looking for major savings opportunities, utilities should make better use of benchmarking as a CI conservation targeting tool.

5. Future research should expand to other categories of CI customers and should also assess the actual levels of efficiency in water uses. Establishments for which the individual end uses are verified to be efficient should be included in the calculation of efficiency benchmarks. Without such verification, the approximate range of efficiency benchmarks will remain relatively wide to allow for the analytical uncertainty in deriving the efficient usage values from data distributions.

APPENDIX A SIC CLASSIFICATIONS FOR CI SECTORS

Table A.1 Nonresidential water use coefficients

(gallons per employee per day)

SIC Code	Description	Sample size	Sample GED	Standard deviation	GED weighted By employment
	TRANSPORTATION AND PUBLIC UTILITIES	225.0	49.3		
40	RAILROAD TRANSPORTATION	3.0	67.6	80	31
401	Railroads	3.0	67.7		
41	LOCAL & INTERURBAN PASSEN. TRANS.	32.0	26.0	299	24
411	Local & Suburban Transportation	3.0	33.0	17	33
412	Taxicabs	10.0	17.2	18	15
413	Intercity & Rural Bus Transport.	2.0	19.5	6	18
414	Bus Charter Service	5.0	25.4	20	33
415	School Buses	1.0	1.0	0	1
417	Bus Terminal & Ser. Fac.	11.0	129.0	488	129
42	TRUCKING AND WAREHOUSING	100.0	84.6	442	43
421	Trucking & Courier Serv., Ex. Air	73.0	29.8	136	23
422	Public Warehousing & Storage	26.0	229.6	821	99
423	Trucking Terminal Facilities	1.0	7.0	0	7
43	U.S. POSTAL SERVICE	1.0	5.1	0	5
431	U.S. Postal Service	1.0	5.1	0	5
44	WATER TRANSPORTATION	10.0	352.8	986	200
441	Deep Sea Foreign Trans. of Freight	3.0	982.3	848	522
442	Deep Sea Dom. trans. of Freight	1.0	2,396.0	0	2,396
443	Freight Trans. on the Great Lakes	--	--	0	2,209
444	Water Transpor. of Freight, NEC	--	--		

(continued)

Table A.1 (Continued)

SIC Code	Description	Sample size	Sample GED	Standard deviation	GED weighted By employment
448	Water Transpor. of Passengers	1.0	2,209.0		
449	Water Transportation Services	5.0	99.2		
45	TRANSPORATION BY AIR	17.0	171.1	376	116
451	Air Transportation, Scheduled	4.0	23.0	757	23
452	Air Trans. Nonscheduled	1.0	13.0	0	13
458	Airports, Flying Fields & Serv.	12.0	217.4	163	134
46	PIPELINES, EXCEPT NATURAL GAS	--	--		
461	Pipelines, Except Natural Gas	--	--		
47	TRANSPORATION SERVICES	13.0	39.8	180	34
472	Passenger Trans. Arrangement	9.0	129.7	181	72
473	Freight Trans. Arrangement	4.0	29.8		
474	Rentals of Railroad Cars	--	--		
478	Mis. Transportation Service	--	--		
48	COMMUNICATIONS	30.0	47.3	113	31
481	Telephone Communications	5.0	45.0	73	21
482	Telegraph & Other Communications	1.0	46.0		
483	Radio & Television Broadcasting	19.0	64.2	135	53
484	Cable & Other Pay TV Services	1.0	5.0	0	5
489	Communications Service, NEC	4.0	13.3	14	23
49	ELECTRIC, GAS, & SANITARY SERV.	19.0	51.0	208	29
491	Electric Service	3.0	197.0	149	210
492	Gas production & Distribution	5.0	8.6	9	10
493	Combination Utility Services	1.0	5.0	0	5
494	Water Supply	1.0	27.0	0	27

(continued)

Table A.1 (Continued)

SIC Code	Description	Sample size	Sample GED	Standard deviation	GED weighted By employment
495	Sanitary Services	9.0	48.1	285	39
496	Steam & Air-Conditioning Supply	--	--		
497	Irrigation Systems	--	--		
	WHOLESALE TRADE	750.0	42.8		
50	WHOLESALE TRADE-DURABLE GOODS	517.0	29.0	492	40
501	Motor Vehicles, Parts, & Supplies	71.0	39.5	64	27
502	Furniture and Home furnishings	22.0	52.0	1,673	34
503	Lumber & Construction Materials	45.0	49.3	420	43
504	Professional & Commercial Equip.	16.0	29.6	48	27
505	Metals & Minerals, Except Petro.	12.0	16.9	40	17
506	Electrical Goods	72.0	21.4	827	129
507	Hardware, Plumb. & Heat. Equip.	63.0	49.4	121	44
508	Machinery, Equipment, & Supplies	186.0	24.5	171	21
509	Misc. Durable Goods	30.0	44.8	83	37
51	WHOLESALE TRADE-NONDURABLE GOODS	233.0	86.7	409	78
511	Paper and Paper Products	25.0	54.3	421	31
512	Drugs, Proprietaries, & Sundries	6.0	59.0	701	36
513	Apparel, Piece Goods, and Notions	15.0	39.1	495	45
514	Groceries and Related Products	76.0	102.8	536	98
515	Farm-Product Raw Materials	5.0	44.8	17	46
516	Chemicals and Allied Products	18.0	45.9	69	73
517	Petroleum and Petroleum Products	17.0	57.3	98	86
518	Beer, Wine, & Distilled Beverages	21.0	24.2	56	28
519	Misc. Nondurable Goods	50.0	269.2	345	135

(continued)

Table A.1 (Continued)

SIC Code	Description	Sample size	Sample GED	Standard deviation	GED weighted By employment
	RETAIL TRADE	1,041.0	93.1		
52	BUILD. MATERIALS & GARDEN SUPPL.	56.0	34.6	105	26
521	Lumber & Other Building Materials	30.0	26.2	108	22
523	Paint, Glass, & Wallpaper Stores	6.0	103.0	183	27
525	Hardware Stores	15.0	35.9	63	34
526	Retail Nurseries & Garden Stores	4.0	57.5	29	43
527	Mobile Home Dealers	1.0	19.0	0	19
53	GENERAL MERCHANDISE STORES	47.0	46.8	79	35
531	Department Stores	29.0	53.9	87	36
533	Variety Stores	8.0	21.3	95	26
539	Misc. General Mech. Stores	10.0	22.0	25	31
54	FOOD STORES	90.0	97.9	490	95
541	Grocery Stores	69.0	94.2	529	85
542	Meat & Fish Markets	3.0	87.7	22	89
543	Fruit & Vegetable Markets	1.0	94.0	0	94
544	Candy, Nut, & Confection Stores	1.0	58.0	0	58
545	Dairy Products Stores	3.0	531.3	736	676
546	Retail Bakeries	10.0	83.1	316	70
549	Misc. Food Stores	3.0	336.0	258	447
55	AUTO DEALERS & SERVICE STATIONS	198.0	48.9	205	60
551	New and used Car Dealers	97.0	33.1	42	34
552	Used Car Dealers	2.0	46.0	54	12
553	Auto and Home Supply Stores	18.0	141.2	264	52
554	Gasoline Service Stations	72.0	117.5	302	343

(continued)

Table A.1 (Continued)

SIC Code	Description	Sample size	Sample GED	Standard deviation	GED weighted By employment
555	Boat Dealers	4.0	33.3	16	31
556	Recreational Vehicle Dealers	1.0	5.0	0	5
557	Motorcycle Dealers	4.0	20.0	17	20
559	Automotive Dealers, NEC	--	--		
56	APPAREL AND ACCESSORY STORES	48.0	67.7	302	61
561	Men's & Boys' Clothing Stores	15.0	27.9	112	21
562	Women's Clothing Stores	11.0	105.8	203	81
563	Women's Access. & Special. Stores	2.0	93.0	0	40
564	Children's & Infants' Wear Stores	--	--		
565	Family Clothing Stores	11.0	20.5	25	22
566	Shoe Stores	3.0	47.7	59	55
569	Misc. Apparel & Accessory Stores	6.0	553.5	687	299
57	FURNITURE & HOMEFURNISH. STORES	100.0	41.7	169	31
571	Furniture & Home furnish. Stores	71.0	35.9	195	30
572	Household Appliance Stores	10.0	26.4	26	20
573	Radio, TV, & Computer Stores	19.0	66.1	96	39
58	EATING AND DRINKING PLACES	341.0	156.2	553	125
581	Eating & Drinking Places	341.0	156.2	553	125
59	MISCELLANEOUS RETAIL	161.0	132.2	704	33
591	Drug Store and Proprietary Stores	10.0	107.5	366	19
592	Liquor Stores	13.0	85.0	118	61
593	Used Merchandise Stores	9.0	70.6	185	76
594	Misc. Shopping Goods Stores	57.0	71.2	944	45
596	Non-store Retailers	18.0	245.6	592	34

(continued)

Table A.1 (Continued)

SIC Code	Description	Sample size	Sample GED	Standard deviation	GED weighted By employment
598	Fuel Dealers	11.0	7.0	51	7
599	Retail Stores, NEC	43.0	320.0	696	237
	FINANCE, INSURANCE, & REAL ESTATE	233.0	182.1		
60	DEPOSITORY INSTITUTIONS	97.0	58.9	189	43
601	Central Reserve Depositories	2.0	161.0	156	90
602	Commercial Banks	70.0	58.3	191	40
603	Savings Institutions	21.0	74.2	0	478
606	Credit Unions	2.0	73.0	111	73
608	Foreign Band & Branches & Agencies	1.0	10.0	0	10
609	Funct. Closely Related to Banking	1.0	29.0		
61	NONDEPOSITORY INSTITUTIONS	12.0	156.4	1,702	119
611	Federal & Fed.-Sponsored Credit	--	--		
614	Personal Credit Institutions	6.0	91.2	73	77
615	Business Credit Institutions	--	--		
616	Mortgage Bankers & Brokers	8.0	190.7	3,502	468
62	SECURITY & COMMODITY BROKERS	2.0	1,239.8	1,742	120
621	Security Brokers & Dealers	1.0	8.0	0	8
622	Commodity Con. Brokers, Dealers	--	--		
623	Security & Commodity Exchanges	--	--		
628	Security & Commodity Services	1.0	2,472.0	0	2,472
63	INSURANCE CARRIERS	9.0	136.3	313	41
631	Life Insurance	3.0	18.0	8	18
632	Medical Service and Health Insur.	1.0	966.0	0	966
633	Fire, Marine, & Casualty Insur.	--	--		

(continued)

Table A.1 (Continued)

SIC Code	Description	Sample size	Sample GED	Standard deviation	GED weighted By employment
635	Surety Insurance	--	--		
636	Title Insurance	3.0	51.0	69	13
637	Pension, Health, & Welfare Funds	--	--		
639	Insurance Carriers, NEC	2.0	28.0		
64	INSUR. AGENTS, BROKERS & SERVICE	24.0	88.9	363	105
641	Insur. Agents, Brokers, & Service	24.0	89.0	363	105
65	REAL ESTATE	84.0	609.0	5,985	705
651	Real Estate Operators & Lessors	25.0	1,403.0	7,631	1,489
653	Real Estate Agents & Managers	39.0	93.1	4,125	110
654	Title Abstract Offices	--	--		
655	Subdividers & Developers	20.0	2,321.0	6,706	1,920
67	HOLDING & OTHER INVESTMENT OFF.	5.0	289.6	503	73
671	Holding Offices	4.0	63.0	157	64
672	Investment Offices	--	--		
673	Trusts	--	--		
679	Misc. Investing	1.0	1,197.0	0	1,197
	SERVICES	1,870.0	137.5		
70	HOTELS & OTHER LODGING PLACES	197.0	229.8	1,491	213
701	Hotels and Motels	191.0	230.3	879	218
702	Rooming & Boarding Houses	2.0	164.0	37	164
703	Camps & Recreation Vehicle Parks	3.0	2,609.5	9,844	181
704	Membership-Basis Organ. Hotels	1.0	4.0	0	4
72	PERSONAL SERVICES	300.0	462.1	1,174	419
721	Laundry, Clean., & Garment Serv.	207.0	516.7	1,319	448

(continued)

Table A.1 (Continued)

SIC Code	Description	Sample size	Sample GED	Standard deviation	GED weighted By employment
722	Photographic Studios, Portrait	3.0	184.0	150	227
723	Beauty Shops	46.0	215.6	637	172
724	Barber Shops	23.0	160.3	156	143
725	Shoe Repair & Shoeshine Parlors	1.0	16.0	0	16
726	Funeral Service & Crematories	15.0	110.6	109	107
729	Misc. Personal Services	5.0	128.8	690	144
73	BUSINESS SERVICES	192.0	57.9	728	73
731	Advertising	20.0	116.4	198	102
732	Credit Reporting & Collection	5.0	61.4	34	68
733	Mailing, Reproduction, Steno.	31.0	111.6	1,827	125
734	Services to Buildings	13.0	67.2	174	55
735	Misc. Equipment Rental & Leasing	1.0	28.5	0	22
736	Personnel Supply Services	7.0	483.4	393	128
737	Computer & Data Processing Serv.	21.0	40.0	465	37
738	Misc. Business Services	74.0	84.1	102	33
75	AUTO REPAIR, SERVICES AND PARK.	108.0	216.6	1,805	179
751	Automotive Rentals, No. Drivers	20.0	147.2	133	87
752	Automotive Parking	2.0	29.0	27	13
753	Automotive Repair Shops	49.0	54.5	108	41
754	Automotive Ser., Except Repair	37.0	680.8	2,755	568
76	MISC. REPAIR SERVICE	41.0	70.7	166	60
762	Electrical Repair Shops	10.0	37.4	30	19
763	Watch, Clock, and Jewelry Repair	1.0	50.0	0	50
764	Reupholstery & Furniture Repair	7.0	81.7	346	45

(continued)

Table A.1 (Continued)

SIC Code	Description	Sample size	Sample GED	Standard deviation	GED weighted By employment
769	Misc. Repair Shops	23.0	124.3	122	75
78	MOTION PICTURES	40.0	112.9	725	13
781	Motion Picture Production & Serv.	22.0	62.8	94	12
782	Motion Picture Distrib. & Serv.	3.0	1,835.0	1,947	1,137
783	Motion Picture Theaters	14.0	259.0	412	259
784	Video Tape Rentals	1.0	57.0		
79	AMUSEMENT & RECREATION SERVICES	106.0	427.1	30,565	471
791	Dance Studios, Schools, and Halls	2.0	197.5	22	211
792	Producers, Orchestras, Entertain.	6.0	36.2	54	26
793	Bowling Centers	14.0	85.6	773	86
794	Commercial Sports	13.0	390.8	876	281
799	Misc. Amusement Recreation Serv.	71.0	597.8	37,251	508
80	HEALTH SERVIES	354.0	90.6	743	85
801	Offices & Clinics of Med. Doctors	56.0	202.9	1,210	183
802	Offices & Clinics of Dentists	22.0	258.7	242	231
803	Offices of Osteopathic Physicians	1.0	159.0	0	159
804	Offices of Other Health Practit.	5.0	194.4	291	186
805	Nursing & Personal Care Fac.	106.0	196.7	477	198
806	Hospitals	122.0	75.4	94	74
807	Medical & Dental Laboratories	10.0	38.6	97	37
808	Home Health Care Services	9.0	55.9	95	78
809	Health and Allied Services, NEC	23.0	168.1	1,639	83
81	LEGAL SERVICES	12.0	76.3	2,330	821
811	Legal Services	12.0	76.0	2,330	821

(continued)

Table A.1 (Continued)

SIC Code	Description	Sample size	Sample GED	Standard deviation	GED weighted By employment
82	EDUCATIONAL SERVICES	296.0	115.8	1,060	104
821	Elementary & Secondary Schools	207.0	168.8	1,225	177
822	Colleges & Universities	36.0	74.8	225	71
823	Libraries	12.0	254.4	624	143
824	Vocational Schools	12.0	355.4	717	162
83	SOCIAL SERVICES	55.0	106.4	568	71
832	Individual and Family Services	12.0	158.0	389	138
833	Job Training & Related Services	3.0	141.3	162	75
835	Child Care Services	17.0	119.5	915	54
836	Residential Care	9.0	110.6	155	68
839	Social Service, NEC	14.0	42.2	218	23
84	MUSEUMS, BOTANICAL, ZOO. GARDENS	9.0	208.0	356	210
841	Museums and Art Galleries	5.0	22.6	167	19
842	Botanical and Zoo. Gardens	4.0	391.3	448	247
86	MEMBERSHIP ORGANIZATIONS	45.0	212.3	442	99
861	Business Association	3.0	159.7	151	167
862	Professional Organization	4.0	251.0	879	134
863	Labor Organizations	2.0	39.0	16	39
864	Civic & Social Associations	12.0	121.6	202	99
865	Political Organizations	--	--		
866	Religious Organizations	20.0	327.9	497	196
869	Membership Organizations, NEC	4.0	13.0	8	14
87	ENGINEERING & MANAGEMENT SERVIES	114.0	87.1	1,014	58
871	Engineering & Architectural Serv.	43.0	37.5	0	43

(continued)

Table A.1 (Continued)

SIC Code	Description	Sample size	Sample GED	Standard deviation	GED weighted By employment
872	Accounting, Auditing, & Book.	14.0	120.3		
873	Research & Testing Services	30.0	122.7	78	56
874	Management & Public Relations	27.0	433.1	1,609	82
88	PRIVATE HOUSEHOLDS	0.0	0.0		
881	Private Households	0.0	0.0		
89	SERVICES	1.0	81.0	192	57
899	Services, NEC	1.0	81.0	0	81
	PUBLIC ADMINISTRATION (91-97)	25.0	105.7		

Davis, W.Y., D. Rodrigo, E.M. Opitz, B. Dziegielewski, D. Baumann, and J. Boland. 1987. IWR-MAIN Water Use Forecasting System, Version 5.1: User's Manual and System Description. Carbondale, Ill.: Planning and Management Consultants, Ltd.
Bureau of the Census. 1986. Census of Manufacturers: Water Use in Manufacturing. U.S. Department of Commerce,: Washington, DC.

Table A.2 Analysis of selected common CI categories

Applicable City	Customer category Description	Number of Customers	Total 1997 Use (hcf)	Percent of total CI customers	Percent of total CI use	Average annual daily use (gpdc)	Std. Dev. Of avg. annual Daily use	Scaled Avg. Daily Use (gpdc)	Percent Seasonal Use
	Irrigation								
IR	IRRIGATION	2404	6471968	38.26	0.2999628	5517.09714	22120.0711	1654.924	0.87236
S. MONICA	LANDSCAPE - COMMERCIAL	44	21970	2.06	0.0142	1023.26027	1849.59	14.81	0.5217
	LANDSCAPE - MUNICIPAL	86	87539	4.03	0.0566108	2085.98827	4589.31970	120.3137	0.71430
	LANDSCAPE - PUBLIC SCHOOLS	2	1750	0.09	0.0011317	1793.15068	303.907423	2.046154	0.62971
	Logical-Weighted Average / Total	2536	6583227	30.22	0.2848114	2595.9097	22668.7614	739.3447	0.86902
	Schools and Colleges								
PHX	SCHOOLS	632	2066256	2.77	0.0654697	6700.01512	10434.8788	439.7116	0.57674
LADWP	SCHOOLS	1424	2494943	5.76	0.1183879	3590.53671	4454.93223	430.7715	0.62460
	COLLEGES AND UNIVERSITIES	253	876642	1.02	0.0415976	7100.85241	10527.9088	295.1964	0.52100
	EDUCATIONAL SERVICES	227	148975	0.92	0.0070690	1344.91943	3131.44481	9.609392	0.33690
S. DIEGO	EDUCATIONAL SERVICES	521	1010304	2.96	0.0408652	3973.95625	20054.0507	230.5142	0.58314
S. MONICA	SCHOOLS	93	70309	4.36	0.0454683	1549.30422	2846.34454	71.72934	0.29268
	Logical-Weighted Average / Total	3150	6667429	4.79	0.0883843	2116.64412	25683.5075	187.0783	0.57993
	Hotels								
LADWP	HOTELS AND MOTELS	803	2086331	3.25	0.0989988	5324.47018	7781.12776	535.2755	0.28587
PHX	HOTEL; MOTEL	338	1856730	1.48	0.0588308	11257.4697	27854.1274	664.7666	0.16401
S. DIEGO	HOTELS AND OTHER LODGING PLACES	82	265255	0.47	0.0107291	6629.15937	19273.6965	91.53065	0.34414
S. MONICA	HOTEL W/DINING FACILITY	20	121525	0.94	0.0785894	12452.1506	12928.2790	997.4076	0.09599
	HOTELS W/O DINING FACILITIES	23	64274	1.08	0.0415655	5726.85550	10268.6435	241.1583	0.15139
	Logical-Weighted Average / Total	1266	4394115	1.92	0.0582490	7112.8958	38476.7356	414.3191	0.23068
	Laundries and Laundromats								
PHX	LAUNDRIES; COMMERCIAL	32	81845	0.14	0.0025932	5241.44349	6514.17293	13.63844	0.09961
	LAUNDRY; SELF SERVICE	82	308501	0.36	0.0097749	7709.94814	7276.76053	75.87171	0.10647
LADWP	COIN-OPERATED LAUNDRIES	518	1923703	2.10	0.0912819	7610.56669	6352.99409	714.6293	0.10239
S. DIEGO	LAUNDRY, CLEANING AND GARMENT SERVICES	107	232408	0.61	0.0094005	4451.18893	25987.5873	46.11973	0.46140
	COIN-OPERATED LAUNDRIES AND CLEANING	142	399514	0.81	0.0161597	5765.70465	4587.26485	103.2425	0.12531

(continued)

Table A.2 (Continued)

Applicable City	Customer category Description	Number of Customers	Total 1997 Use (hcf)	Percent of total CI customers	Percent of total CI use	Average annual daily use (gpdc)	Std. Dev. Of avg. annual Daily use	Scaled Avg. Daily Use (gpdc)	Percent Seasonal Use
S. MONICA	LAUNDROMATS	22	29656	1.03	0.0191783	2762.47671	3484.33295	53.56226	0.05648
	COMMERCIAL LAUNDRY	2	1627	0.09	0.0010521	1667.11780	2073.49164	1.778125	0.40258
	Logical-Weighted Average / Total	905	2977254	1.38	0.0394669	3289.78342	29130.4628	129.8375	0.13354
	Office Buildings								
IR	OFFICE	1530	1340990	24.35	0.0621522	1796.15098	2844.88383	111.6347	0.33394
	OFFICE	3	2752	0.05	1.27550E-0	1879.90502	146.699089	0.239781	0.91279
PHX	OFFICE/BANK BUILDING (NON DINING, MEDICAL, NURSING HOME)	1257	2232526	5.50	0.0707380	3639.73681	5550.21478	258.5845	0.38381
LADWP	NON RESIDENTIAL BUILDING OPERATORS	3487	3983665	14.11	0.1890295	2341.20582	4298.84111	450.0330	0.22294
	Logical-Weighted Average / Total	6277	7559933	11.67	0.1019207	1204.38633	7576.26582	122.7519	0.29039
	Hospitals and Medical Offices								
IR	MEDICAL LAB	37	332347	0.59	0.0154036	18407.6679	77908.7604	283.5448	0.13350
LADWP	HEALTH SERVICES	1407	1458261	5.69	0.0691961	2123.97742	4526.47924	149.0624	0.12166
S. MONICA	HOSPITALS	21	106638	0.98	0.0689620	10406.4219	17370.8356	733.6754	0.07829
	MEDICAL OFFICE FACILITIES	64	49541	3.00	0.0320378	1586.32996	2127.53198	51.66845	0.04621
S. DIEGO	HEALTH AND ALLIED SERVICES, NEC	4	2245	0.02	9.08068E-0	1150.17808	1319.12352	0.104607	0.51277
	HEALTH SERVICES	412	253048	2.34	0.0102353	1258.67737	2390.67627	13.98256	0.40987
	HOSPITALS	36	306436	0.20	0.0123948	17443.9975	54847.7561	388.5963	0.73037
	MEDICAL AND DENTAL LABS	44	33158	0.25	0.0013411	1544.34520	2650.98752	2.424781	0.62772
	VETERINARY SERVICES	41	12847	0.23	5.19641E-0	642.135382	1083.71937	0.348506	0.76242
	Logical-Weighted Average / Total	2066	2554521	4.19	0.0390073	1236.45740	97059.1070	48.23093	0.23163
	Restaurants								
PHX	RESTAURANT, BAKERY	1139	2039912	4.99	0.0646350	3670.25671	4726.67922	238.1904	0.19070
LADWP	EATING AND DRINKING PLACES	4350	3052052	17.60	0.1448234	1437.84279	2111.38693	211.4211	0.08966
S. DIEGO	DRINKING PLACES	133	42457	0.76	0.0017173	654.193758	589.769663	1.178672	0.16918
	EATING AND DRINKING PLACES	1512	1303088	8.60	0.0527078	1766.16261	2707.50330	100.7319	0.30201
	RETAIL BAKERIES	4	703	0.02	2.84353E-0	360.167123	100.648238	0.010769	0.15588
S. MONICA	RESTAURANT & BARS W/ FOOD	206	217727	9.65	0.1408025	2165.97680	3720.49602	309.0399	0.04715

(continued)

Table A.2 (Continued)

Applicable City	Customer category Description	Number of Customers	Total 1997 Use (hcf)	Percent of total CI customers	Percent of total CI use	Average annual daily use (gpdc)	Std. Dev. Of avg. annual Daily use	Scaled Avg. Daily Use (gpdc)	Percent Seasonal Use
	BAKERY OR BAKERY W/ DELI	4	1759	0.19	0.0011375	901.186301	149.373660	1.040294	0.08925
	BARS W/O DINING FACILITIES	8	3209	0.37	0.0020752	822.031506	405.569319	1.730720	0.09878
	Logical-Weighted Average / Total	7356	6660907	11.18	0.0882979	905.506661	6965.40547	79.95436	0.16128
	Food Stores								
IR	FOOD	156	356538	2.48	0.0165248	4683.70958	10830.3285	77.39750	0.17641
LADWP	FOOD STORES	1973	1222326	7.98	0.0580007	1269.60521	2398.07296	74.08504	0.13128
S. DIEGO	FOOD STORES	231	243385	1.31	0.0098445	2159.18851	3941.21553	25.37489	0.50599
	GROCERY STORE	189	40316	1.07	0.0016307	437.143842	585.646966	0.773340	0.37747
S. MONICA	CONVENIENCE & LIQUOR STORES W/ DELI	16	7387	0.75	0.0047771	946.143150	1463.66782	4.592493	0.07484
	Logical-Weighted Average / Total	2565	1869952	5.20	0.0285540	729.026120	11877.0895	20.81663	0.19374
	Auto Shops								
PHX	SERVICE STATION; AUTO REPAIR	634	278114	2.78	0.0088121	898.964055	2442.35156	7.950487	0.29496
LADWP	AUTOMOTIVE DEALERS AND SERVICE STATIONS	2203	657760	8.91	0.0312114	611.873572	1123.85882	19.33105	0.16363
S. DIEGO	AUTOMOTIVE DEALERS AND SERVICE STATIONS	4	246	0.02	9.95032E-0	126.032876	245.160445	0.002508	0.70731
	AUTOMOTIVE REPAIR SHOPS	1304	346333	7.41	0.0140086	544.283309	1110.05386	8.650343	0.35339
	AUTOMOTIVE REPAIR SHOPS, NEC	1	30	0.01	1.21345E-0	61.4794520		7.46025E-	0.4
	AUTOMOTIVE SERVICES, EXCEPT REPAIR	89	152213	0.51	0.0061567	3504.85836	4123.84070	23.67307	0.56466
	AUTOMOTIVE SERVICES, NEC	4	3882	0.02	1.57021E-0	1988.86027	1951.89529	0.327249	0.62959
S. MONICA	AUTO REPAIR, SALES, AND SERVICE STATIONS	194	47067	9.09	0.0304379	497.191300	717.348927	15.38908	0.06126
	Logical-Weighted Average / Total	4433	1485645	6.74	0.0196939	686.793296	5463.60777	13.52565	0.27161
	Membership Organizations								
S. DIEGO	RELIGIOUS ORGANIZATIONS	507	221715	2.88	0.0089680	1008.81580	1974.13228	9.047087	0.50738
IR	CHURCH RATE	826	627517	3.62	0.0198830	1559.84316	3064.37484	31.01437	0.45361
S. MONICA	MEMBERSHIP ORGANIZATIONS	44	16420	2.06	0.0106187	764.767123	1734.14474	8.277779	0.15977
	Logical-Weighted Average / Total	1377	865652	5.60	0.0194905	628.650689	4036.68792	12.25275	0.46181

(continued)

Table A.2 (Continued)

Applicable City	Customer category Description	Number of Customers	Total 1997 Use (hcf)	Percent of total Cl customers	Percent of total CI use	Average annual daily use (gpdc)	Std. Dev. Of avg. annual Daily use	Scaled Avg. Daily Use (gpdc)	Percent Seasonal Use
	Car Wash								
PHX	CAR WASH	85	247814	0.37	0.0078520	5974.69369	5784.29030	47.19628	0.13496
S. MONICA	CAR WASH	4	21957	0.19	0.0141994	126962.241	7467.43921	162.1447	0.22421
	Logical-Weighted Average / Total	89	269771	0.36	0.0081593	3031.13483	9445.66899	24.73203	0.14222

Table A.3

Per employee water use in a sample of 1405 CI establishments in Southern California

SIC Code	Description	Sample Size	Weighted Average Employee-Use (GED)	Mean Employee-Use (GED)	Employee-Use (GED)	
					Min	Max
41	Local and Interurban Passenger Transit	2	20.3	19.3	8.5	30.1
414	Bus Charter service	2	20.3	19.3	8.5	30.1
42	Trucking and Warehousing	20	290.3	424.4	10.5	4,052.8
421	Trucking & Courier Services, Ex Air	13	65.5	166.7	10.5	971.0
422	Public Warehousing and Storage	7	552.9	903.0	55.7	4,052.8
43	US Postal Service	1	5.1	5.1	5.1	5.1
431	US Postal Service	1	5.1	5.1	5.1	5.1
44	Water Transportation	4	612.5	1,311.6	229.9	2,209.8
441	Deep Sea Foreign Transport of Freight	2	1,240.3	1,403.6	750.4	2,056.8
445	Local Water Transportation	1	2,209.4	2,209.4	2,209.4	2,209.4
446	Water Transportation Services	1	229.9	229.9	229.9	229.9
45	Transportation by Air	8	201.4	304.0	6.0	1,528.0
451	Air Transportation Scheduled	3	30.4	522.8	6.0	1,528.0
452	Air Transportation, Nonscheduled	1	13.4	13.4	13.4	13.4
458	Airports, Flying Fields, & Services	4	340.7	212.5	29.6	544.6

(continued)

Table A.3 (Continued)

SIC Code	Description	Sample Size	Weighted Average Employee-Use (GED)	Mean Employee-Use (GED)	Employee-Use (GED)	
47	Transportation Services	6	64.7	167.7	5.3	550.7
471	Freight Forwarding	3	38.9	145.4	5.3	420.3
472	Passenger Transportation Arrangement	3	303.3	190.0	9.0	550.7
48	Communications	8	48.9	52.0	6.6	183.1
481	Telephone Communications	4	52.9	66.7	6.7	183.1
483	Radio and Television Broadcasting	2	57.7	38.7	6.6	70.9
488		1	45.9	45.9	45.9	45.9
489	Communications Services, NEC	1	25.6	25.6	25.6	25.6
49	Electric, Gas, & Sanitary Services	2	32.3	38.3	27.4	49.2
491	Electric Services	1	49.2	49.2	49.2	19.2
495	Sanitary Services	1	27.4	27.4	27.4	27.4
50	Wholesale Trade- Durable Goods	60	19.9	241.7	2.7	7,873.0
501	Motor Vehicles, Parts, and Supplies	3	96.8	92.1	10.2	146.0
502	Furniture and Home furnishings	3	242.7	2,631.2	5.5	7,873.0
503	Lumber and Construction Materials	2	97.9	103.9	86.1	121.7
504	Professional & Commercial Equipment	3	46.8	50.9	4.6	142.0

(continued)

Table A.3 (Continued)

SIC Code	Description	Sample Size	Weighted Average Employee-Use (GED)	Mean Employee-Use (GED)	Employee-Use (GED)	
505	Metals and Minerals, Ex Petroleum	1	5.1	5.1	5.1	5.1
506	Electrical Goods	7	10.7	12.7	3.9	23.8
507	Hardware, Plumbing, & Heating Equipment	3	19.8	11.2	4.1	20.6
508	Machinery, Equipment, and Supplies	35	17.9	150.7	2.7	1,366.5
509	Miscellaneous Durable Goods	3	133.9	190.5	11.6	346.0
51	Wholesale Trade- Nondurable Goods	32	240.1	342.2	4.1	2,126.3
511	Paper and Paper Products	2	406.1	1,085.1	44.0	2,126.3
512	Drugs, Proprietaries, and Sundries	2	140.8	886.6	34.2	1,739.0
513	Apparel, Piece Goods, and Notions	5	44.2	38.8	9.0	91.5
514	Groceries and Related Products	12	149.3	197.9	4.1	655.4
516	Chemicals and Allied Products	2	29.4	31.8	27.6	36.0
519	Misc. Nondurable Goods	9	1,228.1	485.9	38.6	1,898.4
52	Building Materials & Garden Supplies	12	56.5	139.2	11.2	545.0
521	Lumber and Other Building Materials	4	48.3	203.0	15.4	545.0
523	Plant, Glass, and Wallpaper Stores	1	383.0	383.0	383.0	383.0

(continued)

Table A.3 (Continued)

SIC Code	Description	Sample Size	Weighted Average Employee-Use (GED)	Mean Employee-Use (GED)	Employee-Use (GED)	
525	Hardware Stores	5	49.7	67.0	11.2	241.2
526	Retail Nurseries and Garden Stores	2	84.3	70.1	52.7	87.4
53	General Merchandise Stores	6	35.5	56.6	12.6	225.6
531	Department Stores	4	30.0	69.6	14.1	225.6
533	Variety Stores	1	12.6	12.6	12.6	12.6
539	Misc. General Merchandise Stores	1	48.9	48.9	48.9	48.9
54	Food Stores	26	131.3	335.9	14.8	4,284.9
541	Grocery Stores	21	144.7	352.1	14.8	4,284.9
542	Meat and Fish Market	1	66.7	66.7	66.7	66.7
545	Dairy Products Stores	1	36.1	36.1	36.1	36.1
546	Retail Bakeries	2	80.8	568.7	70.9	1,066.5
549	Misc. Food Stores	1	98.0	98.0	98.0	98.0
55	Automotive Dealers & Service Stations	27	62.6	148.5	3.3	1,079.0
551	New and Used Car Dealers	9	44.2	53.3	8.8	205.7
552	Used Car Dealers	1	84.0	84.0	84.0	84.0
553	Auto and Home Supply Stores	8	259.8	244.1	3.4	1,079.0

(continued)

Table A.3 (Continued)

SIC Code	Description	Sample Size	Weighted Average Employee-Use (GED)	Mean Employee-Use (GED)	Employee-Use (GED)	
554	Gasoline Service Stations	8	106.4	180.9	3.3	1,052.0
555	Boat Dealers	1	44.7	44.7	44.7	44.7
56	Apparel and Accessory Stores	11	54.0	248.4	4.6	1,334.0
561	Men's & Boy's Clothing Stores	1	139.3	139.3	139.3	139.3
562	Women's Clothing Stores	3	191.1	260.4	50.3	673.5
565	Family Clothing Stores	3	9.0	10.8	4.6	14.1
566	Shoe Stores	1	11.0	11.0	11.0	11.0
569	Misc. Apparel & Accessory Stores	3	589.5	589.5	36.5	1,334.0
57	Furniture & Home furnishing Stores	28	79.4	98.6	3.3	370.0
571	Furniture & Home furnishing Stores	19	59.3	82.8	5.3	370.0
572	Household Appliance Stores	1	93.0	93.0	93.0	93.0
573	Radio, TV & Electronic Stores	8	121.3	136.8	3.3	332.4
58	Eating & Drinking Places	153	204.2	280.4	6.3	5,872.7
581	Eating & Drinking Places	153	204.2	280.4	6.3	5,872.7
59	Misc. Retail	65	277.1	442.5	2.7	488.0
591	Drug Stores and Proprietary Stores	2	74.5	62.4	47.7	77.2

(continued)

Table A.3 (Continued)

SIC Code	Description	Sample Size	Weighted Average Employee-Use (GED)	Mean Employee-Use (GED)	Employee-Use (GED)	
592	Liquor Stores	9	101.1	99.6	8.7	448.3
593	Used Merchandise Stores	7	32.5	86.7	2.7	498.0
594	Misc. Shopping Goods Stores	24	143.3	706.0	4.1	4,888.0
596	Nonstore Retailers	5	835.4	575.0	27.9	2,537.9
599	Retail Stores	18	617.2	406.3	8.4	2,260.0
60	Depository Institutions	20	44.9	146.7	6.8	1,392.4
602	Commercial Banks	18	45.3	160.5	6.8	1,392.4
603	Savings Institutions	1	18.3	17.5	17.5	17.5
605	Functions Closely Related to Banking	1	28.7	28.7	28.7	28.7
61	Nondepository Institutions	19	104.2	333.6	24.7	3,238.0
612	Savings and Loan Associations	12	94.1	451.0.5	24.7	2,328.0
614	Personal Credit Institutions	3	119.3	96.4	30.0	221.0
616	Mortgage Bankers and Brokers	4	215.3	157.7	62.2	313.3
62	Security & Commodity Brokers	1	2,471.8	2,471.8	2,471.8	2,471.8
628	Security and Commodity Services	1	2,471.8	2,471.8	2,471.8	2,471.8
63	Insurance Carriers	1	131.2	131.2	131.2	131.2

(continued)

Table A.3 (Continued)

SIC Code	Description	Sample Size	Weighted Average Employee-Use (GED)	Mean Employee-Use (GED)	Employee-Use (GED)	
636	Title Insurance	1	131.2	131.2	131.2	131.2
64	Insurance Agents, Brokers, & Services	13	99.9	340.1	8.0	1,141.4
641	Insurance Agents, Brokers, & Services	13	99.9	340.1	8.0	1,441.4
65	Real Estate	37	1,031.0	3,253.3	6.2	26,918.9
651	Real Estate Operators and Lessors	9	1,220.2	2,260.3	71.0	13,098.0
653	Real Estate Agents and Managers	17	119.1	2,501.7	6.2	23,350.0
655	Subdividers and Developers	11	4,194.2	5,227.4	69.5	26,918.9
66	Combined Real Estates, Insurance, Etc.	1	5,505.5	5,505.5	5,505.5	5,505.5
661	Combined Real Estates, Insurance, Etc.	1	5,505.5	5,505.5	5,505.5	5,505.5
67	Holding and Other Investment Offices	1	1,197.0	1,197.0	1,197.0	1,197.0
679	Misc. Investing	1	1,197.0	1,197.0	1,197.0	1,197.0
70	Hotels and Other Lodging Places	69	186.0	926.1	54.7	5,082.0
701	Hotels and Motels	69	186.0	926.1	54.7	5,082.0
72	Personal Services	110	672.2	648.0	2.1	4,035.0
721	Laundry, Cleaning, & Garment Services	90	664.5	662.6	2.1	4,035.0
722	Photographic Studios, Portrait	3	931.1	364.9	29.6	988.2

(continued)

Table A.3 (Continued)

SIC Code	Description	Sample Size	Weighted Average Employee-Use (GED)	Mean Employee-Use (GED)	Employee-Use (GED)	
723	Beauty Shops	7	833.5	1,018.5	53.3	3,139.8
724	Barber Shops	3	218.9	262.4	77.3	615.0
725	Shoe Repair and Shoeshine Parlors	1	15.4	15.4	15.4	15.4
726	Funeral service and Crematories	2	81.8	94.3	31.8	156.8
729	Misc. Personal Services	4	155.2	607.1	14.1	1,672.2
73	Business Services	84	99.7	234.8	3.3	3,567.0
731	Advertising	5	158.0	272.5	31.1	608.7
732	Credit Reporting and Collection	1	38.9	39.0	39.0	39.0
733	Mailing, Reproduction, Stenographic	9	72.5	100.0	3.3	342.0
734	Services to Buildings	5	101.9	172.5	11.7	350.0
735	Misc. Equipment Rental & Leasing	1	22.5	22.5	22.5	22.5
736	Personnel Supply Services	5	468.5	333.4	13.1	821.4
737	Computer Programming Services	4	38.9	110.6	24.5	206.0
739	Miscellaneous Business Services	54	122.4	267.2	3.6	3,567.0
75	Auto Repair, Services, and Parking	42	157.7	120.5	5.7	549.9
751	Automotive Rentals, No Drivers	7	343.0	205.1	14.3	549.9

(continued)

Table A.3 (Continued)

SIC Code	Description	Sample Size	Weighted Average Employee-Use (GED)	Mean Employee-Use (GED)	Employee-Use (GED)	
753	Automotive Repair Shops	33	66.2	98.2	8.3	548.0
754	Automotive Services, Except Repair	2	103.6	191.8	5.7	377.8
762	Electrical Repair Shops	7	47.1	40.5	7.2	92.2
763	Watch, Clock, and Jewelry Repair	1	49.6	49.6	49.6	49.6
764	Reupholstery and Furniture Repair	5	102.4	211.0	13.2	943.5
769	Misc. Repair Shops	8	225.9	162.2	25.1	506.1
78	Motion Pictures	21	78.2	127.9	7.2	943.5
781	Motion Picture Production & Services	10	10.3	110.3	3.1	317.3
782	Motion Picture Theaters	2	2,748.1	3,088.5	2,294.0	3,882.0
79	Amusement & Recreation Services	15	451.7	2,158.5	81.3	15,102.1
791	Dance Studios, Schools, and Halls	1	182.0	182.0	182.0	182.0
793	Bowling Centers	1	81.3	81.3	81.3	81.3
794	Commercial Sports	2	464.2	574.7	243.3	906.2
799	Misc. Amusement, Recreation Services	11	451.8	2,815.0	144.8	15,102.1
80	Health Services	128	95.7	480.9	3.4	5,632.0
801	Offices & Clinics of Medical Doctors	33	237.3	1,286.5	18.8	5,632.7

(continued)

Table A.3 (Continued)

SIC Code	Description	Sample Size	Weighted Average Employee-Use (GED)	Mean Employee-Use (GED)	Employee-Use (GED)	
802	Offices and Clinics of Dentists	9	221.1	174.8	64.9	362.3
804	Offices of Other Health Practitioners	4	64.6	67.7	26.7	131.2
805	Nursing and Personal Care Facilities	28	380.6	412.2	28.5	4,090.4
806	Hospitals	46	71.7	75.5	5.1	248.7
807	Medical and Dental Laboratories	3	18.8	100.5	3.4	283.3
808	Home Health Care Services	2	115.9	99.5	60.0	138.9
809	Health and Allied Services, NEC	3	325.0	580.7	8.5	1,280.0
81	Legal Services	15	821.1	1,248.1	4.0	7,101.0
811	Legal Services	15	821.1	1,248.1	4.0	7,101.0
82	Educational Services	207	145.8	546.9	8.4	12,792.0
821	Elementary and Secondary Schools	159	195.7	623.3	9.4	12,792.0
822	Colleges and Universities	14	137.2	232.5	8.4	1,281.0
823	Libraries	7	376.4	626.0	87.4	2,264.0
824	Vocational Schools	4	67.5	60.0	40.6	171.0
829	Schools & Educational Services	22	180.3	269.7	23.8	1,398.7
83	Social Services	16	210.3	710.8	32.2	2,867.0

(continued)

Table A.3 (Continued)

SIC Code	Description	Sample Size	Weighted Average Employee-Use (GED)	Mean Employee-Use (GED)	Employee-Use (GED)	
832	Individual and Family Services	4	219.7	463.6	38.1	1,399.5
835	Child Day Care Services	8	210.1	984.3	34.2	2,867.0
836	Residential Care	2	263.0	352.3	173.7	531.0
839	Social Services, NEC	2	168.5	469.5	101.6	837.3
84	Museums, Botanical, Zoological Gardens	2	211.3	126.7	41.0	212.3
841	Museums and Art Galleries	1	41.0	41.0	41.0	41.0
842	Vocational Schools	1	212.3	212.3	212.3	212.3
86	Membership Organizations	17	413.3	501.7	14.5	2,047.0
861	Business Associations	1	73.5	73.5	73.5	73.5
862	Professional Organizations	2	467.6	1,077.8	293.2	1,862.4
866	Religious Organizations	12	485.4	518.7	14.5	2,047.0
89	Services, NEC	17	109.8	120.8	3.0	572.0
891	Engineering and Architectural Services	8	27.0	109.3	3.0	572.0
892	Noncommercial Research Organizations	1	126.9	126.9	126.9	126.9
893	Accounting, Auditing and Bookkeeping	8	186.7	131.5	6.5	495.1
91	Executive, Legislative, and General	1	25.1	25.1	25.1	25.1

(continued)

Table A.3 (Continued)

SIC Code	Description	Sample Size	Weighted Average Employee-Use (GED)	Mean Employee-Use (GED)	Employee-Use (GED)	
910	Executive, Legislative, and General	1	25.1	25.1	25.1	25.1
94	Finance, Taxation, & Monetary Policy	1	18.9	18.9	18.9	18.9
944	Admin of Social & Manpower Programs	1	18.9	18.9	18.9	18.9
95	Environmental Quality and Housing	1	77.8	77.8	77.8	77.8
951	Environmental Quality	1	77.8	77.8	77.8	77.8
96	Administration of Economic Programs	1	903.5	903.5	903.5	903.5
964	Regulation of Agricultural Marketing	1	903.5	903.5	903.5	903.5
97	National Security and International Affair	1	161.0	161.0	161.0	161.0
970	National Security and International Affair	1	161.0	161.0	161.0	161.0

Source: Dziegielewski, B., D. Rodrigo, and E.M. Opitz. 1990. Commercial and Industrial Water Use in Southern California. Los Angeles, Calif.: The Metropolitan Water Department of Southern California.

APPENDIX B MODEL VARIABLES

The first column in Tables B.1 through B.5 list end uses that can be specified using binary indicator variables (presence = 1 or absence = 0). However, nearly all of these end uses can also be specified as "magnitude/size/count" variables shown in the second column. For example, some restaurants have a bar while others do not. While comparing restaurants with a bar to those without one (while controlling for all other variables that influence the response variable of total water use in a restaurant), it should be possible to estimate average (positive) quantity of water usage in the sample that is associated with the presence of a drinking bar. By adding the count variable in the form of the reported average number of bar customers, it should be possible to estimate the quantity of water use by a bar as a function of the number of customers served.

Variables in the third column are likely to affect several or even all end uses. In a modeling context, one or more of these variables may be specified within a "nested function," which estimates each end use present not only in terms of the size of the activity but also in terms of such predictor variables as price or number of employees.

Table B.1 Model variables for restaurants

Indicator Variables	Size/Count Variables*	Common/Other Variables
Public/employee restrooms	Number of restrooms	Number of employees
	Number of tank-type toilets	Total building area
	Number of valve-type toilets	Number of meters
	Number of urinals	Marginal price of water
	Number of sanitary faucets	Marginal price of sewer
Landscape irrigation	Irrigated area	Number of customers
	Frequency of irrigation per week	Number of meals served
Leaks	Number of leaks	Seating capacity
Fountains	Number of fountains	Operating hours per week
Cooling towers	Number of cooling towers	Estimated irrigation water use
Swamp coolers	Number of swamp coolers	Estimated kitchen water use
Evaporative condensers	Number of condensers	Estimated sanitary water use
Single-pass cooling	Number of single pass coolers	
Hot water boilers	Number of hot water boilers	
Drinking bar	Number of bar customers	
Automatic dishwashing	Number of dishwashers	
	Dishwasher type (flight or rack)	
Kitchen faucets	Number of kitchen faucets	
Scullery nozzles	Number of nozzles	
Kitchen garbage disposal	Number of disposals	
Dishwashing sink	Number of dishwashing sinks	
Floor hoses	Number of hoses	
Utensil bins	Number of utensil bins	
Pot sinks	Number of pot sinks	
Food preparation sinks	Number of food sinks	
Hand washing sinks	Number of hand washing sinks	
Wok faucets	Number of wok faucets	
Water curtain and other uses	Number of other uses	
Rice steamer faucets	Number of rice steamer faucet	
Ice making machine	Number of ice machines	
Washing machine	Number of washing machines	

*As related to the indicator variables

Table B.2 Model variables for hotels

Indicator Variables	Size/Count Variables*	Common/Other Variables
Public restrooms	Number of public restrooms	Number of employees (FTE)
	Number of tank-type toilets	Total building area
	Number of valve-type toilets	Number of water meters
	Number of public urinals	Marginal price of water
	Number of sanitary faucets	Marginal price of sewer
	Number of ULF toilets	Occupancy (percent)
	Number of waterless urinals	Occupancy rate per room
Private bathrooms/restrooms	Number of private bathrooms	Number of rooms
	Number of private tank toilets	Estimated sanitary water use
	Number of private valve toilets	Estimated laundry water use
	Number of private ULF toilets	Estimated irrigation water use
	Number of private faucets	Estimated kitchen water use
	Number of tub showers	Estimated cooling water use
	Number of stall showers	Estimated pool and spa water use
Lounges	Number of lounges	
Kitchens	Number of kitchens	
Laundries	Number of laundry rooms	
Washing machines	Number of washers (type 1)	
	Number of washers (type 2)	
	Number of washer extractors	
Pools	Number of pools	
	Total pool capacity	
Spa/Jacuzzi/whirlpool	Number of spas	
	Capacity of spas	
	Estimated water use per spa	
Health club/gym		
Ice making	Number of ice machines	
	Ice machine type	
	Ice machine capacity	
Irrigation	Type of irrigation	
	Total irrigated area	
Leaks	Number of leaks	
Fountains		
Cooling towers	Number of cooling towers	
	Cooling tower type	
	Cooling tower capacity	
Restaurant		
Automatic dishwashers	Number of dishwashers	
	Number of flight dishwashers	
	Number of rack dishwashers	
Kitchen and food prep. Faucets	Number of Faucets	
Scullery nozzles	Number of nozzles	
Disposals	Number of disposals	
Utensil bin	Number of utensil bins	
Pot sinks	Number of pot sinks	
Food preparation sinks	Number of food prep sinks	
Hand washing sink	Number of hand washing sinks	

*As related to the indicator variables

Table B.3 Model variables for grocery stores

Indicator Variables	Size/Count Variables*	Common/Other Variables
Store departments		Number of employees (FTE)
Hair salon		Total building area
Bakery		Number of water meters
Meet shop		Marginal price of water
Dairy		Marginal price of sewer
Produce		Operating days per year
Seafood		Operating hours per week
Live Fish Aquarium		Number of customers per week
Floral		Estimated kitchen water use
Deli		Estimated sanitary water use
Express booth		Estimated cleaning water use
Juice Bar		Estimated irrigation water use
Restaurant		Estimated food prep water use
Public/Employee Restrooms	Number of public restrooms	Estimated mister water use
	Number of tank-type toilets	Estimated refrigeration water use
	Number of valve-type toilets	Estimated produce hose water use
	Number of public urinals	Estimated leaks water use
	Number of sanitary faucets	Estimated cooling water use
	Number of ULF toilets	Estimated ice making water use
Washing machines (domestic)	Number of washers	
Water treatment		
Ice making	Number of ice machines	
Produce mist sprayer	Number of sprayers	
Produce grinder	Number of grinders	
Irrigation	Total irrigated area	
	Irrigation meter	
Leaks	Number of leaks	
	Leak rate	
Cooling towers	Number of cooling towers	
	Cooling tower capacity	
Evaporative condensers	Number of evaporative condensers	
	Evap. Condenser capacity (tons)	
Restaurant		
Automatic dishwashers	Number of rack dishwashers	
Utility sink	Number of utility sinks	
Department sink	Number of department sinks	
Floor hose	Number of hoses	
Scullery nozzles	Number of nozzles	
Disposals/garbage grinder	Number of disposals	
Produce sink	Number of produce sinks	
Pot sinks	Number of pot sinks	
Food preparation sinks	Number of food prep sinks	
Hand washing sink	Number of hand washing sinks	

*As related to the indicator variables

Table B.4 Model variables for office buildings

Indicator Variables	Size/Count Variables*	Common/Other Variables
Restaurants	Number of restaurants	Number of employees (FTE)
	Total seating capacity	Total building area
Deli	Number of delis	Number of water meters
Health club	Number of health clubs	Marginal price of water
Kitchenettes	Number of kitchenettes	Marginal price of sewer
	Number of kitchen sinks	Operating days/year
Fitness center	Number of fitness centers	Operating hours per week
Conference center		Number of businesses
Kitchen	Number of kitchens	Number of buildings
Display fountain	Number of display fountains	Number of stories
	Display coverage/area	Average occupancy
Mechanic shop	Number of mechanic shops	Estimated sanitary water use
Print shop	Number of print shops	Estimated cleaning water use
Car wash	Number of car washes	Estimated irrigation water use
Dry cleaners	Number of dry cleaners	Estimated kitchen water use
Ice making company	Number of ice companies	Estimated cooling water use
Laundry facility	Number of laundries	Estimated ice making water use
Washing machines	Number of washing machines	Estimated medical water use
	Water use per pond of clothes	Estimated fountain water use
Bottled water store	Number of bottled water stores	Estimated lake use
Hair salon	Number of hair salons	Estimated car wash water use
Pharmacy	Number of pharmacies	Estimated dry cleaning water use
Misting room	Number of mist rooms	Est. washing machine water use
Misting area	Number of mist areas	Est. manufacturing use
	Number of misters	
Laboratory	Number of laboratories	
Swimming pool	Swimming pool capacity	
Public restrooms	Number of public restrooms	
	Number of tank toilets	
	Number of valve toilets	
	Number of public urinals	
	Number of sanitary faucets	
	Number of ULF toilets	
	Number of waterless urinals	
	Number of showers	
Jacuzzi	Number of Jacuzzis	
Wash stations	Number of wash stations	
Kitchens	Number of kitchens	
Ice making	Number of ice machines	
Irrigation	Number of irrigation	
	Total irrigated area	
Leaks	Number of leaks	
Cooling towers	Number of cooling towers	
	Cooling tower capacity	

(continued)

Table B.4 (Continued)

Indicator Variables	**Size/Count Variables***	**Common/Other Variables**
Chillers	Number of chillers	
	Chiller capacity	
Swamp coolers	Number of swamp coolers	
	Swamp cooler capacity	
Evaporative condensers	Number of evap. condensers	
	Evaporative condenser type	
	Evap. condenser capacity	
Restaurants (other end uses also)		
Kitchen faucets	Number of kitchen faucets	
Automatic dishwashers	Number of dishwashers	
	Number of flight dishwashers	
	Number of rack dishwashers	
Kitchen and food prep faucets	Number of faucets	
Scullery nozzles	Number of nozzles	
Disposals	Number of disposals	
Utensil bin	Number of utensil bins	
Pot sinks	Number of pot sinks	
Food preparation sinks	Number of food prep sinks	
Hand washing sink	Number of hand washing sinks	

*As related to the indicator variables

Table B.5 Model variables for schools

Indicator Variables	Size/Count Variables*	Common/Other Variables
Restrooms	Number of restrooms (572)	Number of employees (FTE)
	Number of tank-type toilets (570)	Total building area
	Number of valve toilets (6599)	Number of water meters
	Number of urinals (2949)	Marginal price of water
	Number of sanitary faucets(6891)	Marginal price of sewer
	Number of ULF toilets (340)	Number of pupils
	Number of waterless urinals (10)	Occupancy
Gym showers	Total number of showers (2551)	Operating hours (irrigation)
Swimming pools	Number of pools (26)	Estimated irrigation water use
Irrigation	Type of irrigation	
	Total irrigated area	
	Operating days/year	
	Irrigation meter	
Leaks (15/139)		
Fountains	Number of fountains (92)	
Cooling towers	Number of cooling towers (61)	
	Cooling tower type	
	Cooling tower capacity	
Swamp cooler	Number of swamp coolers (13)	
Evaporative condensers	Number of condensers (54)	
Steam boilers	Number of boilers (21)	
Water treatment		
Restaurant (59/139)	Meals served (75133)	
Automatic dishwashers	Number of dishwashers (8)	
	Number of flight dishwashers (4)	
	Number of rack dishwashers (39)	
Kitchen and food prep faucets	Number of faucets (7)	
Scullery nozzles	Number of nozzles (61)	
Disposals	Number of disposals (11)	
Utensil bin	Number of utensil bins (124)	
Pot sinks	Number of pot sinks (167)	
Food preparation sinks	Number of food prep sinks (126)	
Hand washing sink	Number of hand washing sinks (209)	

*As related to the indicator variables

APPENDIX C INTERNAL VALIDITY OF NON-RESIDENTIAL ECONOMETRIC WATER USE MODELS: A DISCUSSION

Review comments on the validity of the CDA models were provided by: Alok Bohara (AB), Associate Professor, University of New Mexico; Subhash C. Sharma (SS), Professor, Department of Economics, Southern Illinois University; and Kenneth Train (KT), Professor, Center for Regulatory Policy, University of California, Berkeley

The theoretical equations presented in the main body of the report raise a number of methodological questions. These equations are numbered and presented below to facilitate the discussion (all the variables are defined already in the report). The equations are as follows:

$$Q_k = a + \Sigma b_i D_{ki} + \varepsilon_k \tag{C.1}$$

$$Q_k = a + \Sigma b_i D^*_{ki} + \Sigma c_j S_j + \varepsilon_k \tag{C.2}$$

$$b_{dw} = \alpha_{dw} + \beta_{dw} M + \delta_{dw} P + \phi_{dw} N + \varepsilon_{dw} \tag{C.3}$$

$$b_{ir} = \alpha_{ir} + \beta_{ir} A + \delta_{ir} P + \phi_{ir} W + \varepsilon_{ir} \tag{C.4}$$

$$\begin{aligned} Q_k = a &+ (\alpha_{dw} + \beta_{dw} M + \delta_{dw} P + \phi_{dw} N + \varepsilon_{dw}) D_{dw} \\ &+ (\alpha_{ir} + \beta_{ir} A + \delta_{ir} P + \phi_{ir} W + \varepsilon_{ir}) D_{ir} \\ &+ b_{ice} K_{ice} + b_{bar} D_{bar} + \varepsilon_k \end{aligned} \tag{C.5}$$

$$\begin{aligned} Q_k = a &+ \alpha_{dw} D_{dw} + \alpha_{ir} D_{ir} + \beta_{dw} M.D_{dw} + \delta_{dw} P.D_{dw} \\ &+ \phi_{dw} N.D_{dw} + \beta_{ir} A.D_{ir} + \delta_{ir} P.D_{ir} + \phi_{ir} W.D_{ir} \\ &+ b_{ice} K_{ice} + b_{bar} D_{bar} + \varepsilon_{dw} D_{dw} + \varepsilon_{ir} D_{ir} + \varepsilon_k \end{aligned} \tag{C.6}$$

Questions related to the methodological issues involved in the estimation of CDA models are as follows:

Question 1. *Are the regression coefficients b_i unbiased estimates of the average quantities of water used for each specified end use (purpose) D_i?*

Question 2. *Is intercept a an unbiased estimate of average water use by the "unspecified" and "common" end uses (net of* b_i*) in the sample?*

Question 3. *There is an expectation that* b_i *should be positive. What model specification would ensure that? Are negative values also plausible when considered together with the intercept value a?*

Question 4. *What are the necessary properties of* S_j *and other model requirements to ensure that* c_j *is an unbiased estimator of the average incremental quantity of water used for each end use?*

Question 5. *Can a given end use be specified using both the binary indicator variable* E_i *and the size variable* S_j *within the same equation or is it necessary to use a cross-product specification* D_j*S_j*?*

Question 6. *When estimated through the regression, the above specification suggests that the intercept and the error term for a specific end use will be estimated together as the coefficient of D. is this true?*

Question 7. *Which model estimation procedure will produce unbiased estimates of the intercept, the regression coefficients of the binary, count and cross-product variables? Is EGLS procedure with the error term composed of one element that is unique to each establishment and another representing white noise appropriate?*

Question 8. *Given the presence of nonzero value for intercept a, and the overall model error, is it possible to "extract" an unbiased predictive equation for each end use with the "nested" specification (i.e., in which the LHS is the quantity of water used for the specific end use)?*

Question 9. *Can the error term* ϵ_k *be allocated into the individual nested models that are extracted for predicting individual end uses? Similarly, can the common intercept be partitioned among the extracted end use model?*

Question 10. *How should the resultant coefficients be interpreted (see Question 7), when the establishment total metered water use variable (the LHS variable) is logarithmically transformed prior to estimation (i.e., exponential transformation)?*

ANSWERS BY THE REVIEW PANEL

Question 1. Are the regression coefficients b_i unbiased estimates of the average quantities of water used for each specified end use purpose D_i?

Bohara

AB: Yes, if there are no omitted variable problems. That is, if the model is properly specified without the omission of any important variables.

Sharma

SS: No. The estimate of the average quantities of water used for i^{th} end use is $(a+b_i)$ not b_i only.

Rationale:

$Q_k = a + b_i$ if $D_{ki} = 1 = a$ if $D_{ki} = 0$

So, $(a+b_i)$ is an unbiased estimate of the average quantities of water used for the i^{th} end use.

Train

KT.: The coefficients are unbiased as long as the factors that are left out of the model are uncorrelated with the included variables. This is the same requirement as for all regression models. Essentially, you want to be sure that the included variables are not picking up the effect of any omitted variables, which would happen if omitted variables are correlated with the included variables.

Question 2. Is intercept a an unbiased estimated of average water use by the unspecified and common end uses(net of b_i) in the sample?

AB: One has to be careful about interpreting the intercept term so casually. It is also sometimes referred to as the "garbage collector." That is, it may be picking up some noises.

SS: Note in ans. 1, $Q_k = a$ when Dki = 0. The intercept a is an unbiased estimate of average water use by the unspecified and common end uses in the sample. Net of b_i is not needed in the statement.

KT: Yes.

Question 3. There is an expectation that b_i should be positive. What model specification would ensure that? Are negative values also plausible when considered together with the intercept value a?

AB: Part one: A constrained least squares method (or maximum likelihood) could be used to ensure the positiveness of the coefficients. Or a non-linear least squares estimation method with an exponentiated coefficient might also do the trick.

Part two: Yes, it is possible to obtain negative values, especially in light of the imprecise estimates leading to wider confidence intervals.

SS: Yes, the negative values of b_i are also plausible when considered together with the intercept value a. In the least squares estimation one can always minimize the sum of squares due to errors subject to certain restrictions on the parameters. In this case, one can estimate model(1) subject to $b_i > 0$.

KT: Usually, the b_i's are expected to be positive. You can ensure that they are positive by estimating with nonlinear least squares and specifying the coefficients to be $\exp(b_i)$. However, I would recommend that you not try to ensure that the coefficients are positive. If the estimates turn out to be negative for some end-use, then usually that means there is some specifications or other error in the model. If the coefficients are forced to be positive, then you won't see that there is a problem. It is possible, as stated in the question, that negative coefficients are plausible. This possibility should be examined on a case-by-case basis.

Question 4. What are the necessary properties of S_j and other model requirements to ensure that C_j is an unbiased estimator of the average incremental quantity of water used for each end use?

AB: One has to be careful about the possibility of multicollinearity problem. That is, many S_j variables may be closely related. Furthermore, because of the count nature of the data (size of a common end use), the design matrix may be unbalanced and may create the outlier problem. Remember, the usual outlier problem is attributed to the dependent variable only. I am referring to the one caused by the right-hand side variable(s).

SS: There are no properties or conditions needed on S_j. As defined, S_j is a given fixed regressor, so the least squares estimation of model (2) will ensure that c_j is an unbiased estimator of c_j. There are no other model requirements needed. As a matter of fact, the c_j is an unbiased estimator of c_j even when the errors are heteroscedastic.

KT: Using count or size variables instead of (or in addition to) indicator variables does not place any new requirements on the model for unbiasedness. The same principle applies: omitted variables need to be uncorrelated with included variables.

Question 5. Can a given end use be specified using both the binary indicator variable D_i and the size variable S_j within the same equation or is it necessary to use a cross-product specification $D_j{*}S_j$?

AB: One cannot use the dummy and the continuous variables reflecting the same series. For example, it is similar to using a continuous income variable on the right hand side and also putting the qualitative variables such as poor, medium, and rich dummies.

SS: Technically, it is not necessary to use a cross-product specification $D_j{*}S_j$. One can use both the binary indicator variable D_j and the size variable S_j within the same equation. However, it is more appropriate to model with the cross-product term. Rational:

$$Q_k = a + \Sigma\, c_jD_jS_j + \ldots + \varepsilon_k = a + \Sigma\, c_jS_j \text{, when } D_j = 1 = a\text{, when } D_j = 0 \qquad \text{(C.7)}$$

So, there are two models built in (C.7). However, if one builds

$$Q_k = a + b_jD_j + c_jS_j + \ldots \qquad \text{(C.8)}$$

When $D_j = 1$, from (C.8)

$$Q_k = (a + b_j) + c_jS_j + \ldots \qquad \text{(C.8a)}$$
$$= a^* + c_jS_j + \ldots.$$

Now $a^* = a$ in (C.7). When $D_j = 0$, this also implies that $S_j = 0$, so from (C.8)

$$Q_k = a. \qquad \text{(C.8b)}$$

Thus, if one use (C.8) then one has to manually control S_j, corresponding to D_j.

KT: Yes. Using the indicator variable and the count variable means that going from 0 to 1 (i.e., from not having the end-use to have a count of 1 for the end-use) has a different effect on water consumption than going from a count of 1 to 2, or from 2 to 3, etc. Whether this is plausible or not depends on the end-use and the count variable that is used. For most end-uses, I imagine that it is a reasonable specification.

Question 6. When estimated through the regression, the above specification suggests that the intercept and the error term for a specific end use will be estimated together as the coefficient of D, is this true?

AB: The model you have becomes a heteroscedastic model, because the composite error does involve some variable, i.e., this implies that the error variances are not constant, so the usual OLS method may not be valid. Although the theory says that the coefficients are still unbiased, the hypothesis testing may be affected because of the biased variances.

SS: Question is not clearly stated. "When estimated through the regression..." is not meaningful. The intercept and the error term for a specific end use will be estimated together as the coefficient of D, is this true? No.

The intercept in model (C.6) is a. When we estimate model (C.6), we get estimates of a, α_{dw} and α_{ir}. etc.

Let $a^* = a + \alpha_{dw}D_{dw} + \alpha_{ir}D_{ir}$ (C.9)

So, if a restaurant has a dishwasher, and no irrigation, then intercept is

$a^* = a + \alpha_{dw}$, if $D_{dw} = 1$, $D_{ir} = 0$ = a, if $D_{dw} = 0$, $D_{ir} = 0$

The error term in model (C.6) is

$\varepsilon_k{}^* = \varepsilon_k + \varepsilon_{dw}D_{dw} + \varepsilon_{ir}D_{ir}$ (C.10)

When model (C.6) is estimated by least squares method, we get an estimate of $\varepsilon_k{}^*$. It is not possible to break $\varepsilon_k{}^*$ into ε_k, ε_{dw}, and ε_{ir}. However, a* is obtained by its different components i.e., a, α_{dw} and α_{ir}.

KT: The intercept for the specific end-use will be estimated as the coefficient of D. The error term for the specific end-use will be incorporated into the overall error of the regression.

Question 7. Which model estimation procedure will produce unbiased estimates of the intercept, the regression coefficients of the binary, count and cross-product variables? Is EGLS procedure with the error term composed of one element that is unique to each establishment and another representing white noise appropriate?

AB: Again, the simultaneous inclusion of the dummy and the continuous variable representing the same series is quite problematic (see Question 5). A GLS method can be tailored to estimate the heteroscadastic model like yours, however.

SS: Which model estimation procedure will produce unbiased estimates of intercept, the regression coefficients of the binary, count and cross-product variable? I do not think that any estimation procedure will produce unbiased estimates. One can get unbiased estimates only if the variance-covariance matrix of the error term in (C.6) is known. Since the variance-covariance matrix of the error term in model (C.6) is unknown, one has to use EGLS procedure. In general, the EGLS estimates are biased but consistent.

Is EGLS procedure with error term composed of one element that is unique to each establishment and another representing white noise appropriate? Yes. Equation(10) above defines that error term. The different establishments of the error term are $\varepsilon_{dw}D_{dw}$ and $\varepsilon_{ir}D_{ir}$ etc.

KT: Again, all that is required for unbiasedness is that the omitted variables not be correlated with the included variables. In theory, it is possible to decompose the overall error into its end-use components. However: (1) Decomposition of the error is not necessary for unbiasedness. The estimated coefficients are still unbiased even if you don't decompose the error into its end-use parts. (2) I doubt you will be successful in getting a reasonable decomposition given the small samples. So, I'd vote not to bother with trying to decompose the error.

Question 8. Given the presence of nonzero value for intercept a, and the overall model error, is it possible to "extract" an unbiased predictive equation for each end use with the "nested" specification (i.e., in which the LHS is the quantity of water used for the specific end use)?

AB: Given the proper model specification (see Q 5 and Q 7), the answer is yes.

SS: Since the estimates (by any method) obtained in model (C.6) will be biased, but consistent. It is not possible to get an unbiased predictive equation. However, the predictive equation will be consistent in the statistical sense.

KT: You to need to assume that the intercept a captures the mean impact of all unincluded end-uses and does not capture a portion of the included end-uses. This is a standard assumption in CDA and seems reasonable since the intercept gives average consumption when all the included end-uses are not present (i.e., the indicators and counts are zero.)

Question 9. Can the error term ε_k be allocated into the individual nested models that are extracted for predicting individual end uses. Similarly, can the common intercept be partitioned among the extracted end use model?

AB: Part one: No, because you have a common (constant) variance for the nested model.

Part two: In a nested model all you can do is put different dummy indicator variable and extract the relevant end use model. So, the intercept are simply adjusted up or down for different extracted model. The common intercept itself cannot be decomposed per se. And I do not see any reason for doing so. At least I do not see the purpose.

An alternate modeling strategy you may think about is to do a seemingly unrelated model for a set of important end use equations (around not more than 6 or so equations). It allows different error structure, different variances, and also allows any inter-end-use interactions (correlations). Furthermore, it also estimates different sets of coefficients.

SS: Note that ε_k is not the error term in model (C.6), it is ε_k*, see equation (C.10). The estimated error term, ε_k*, cannot be allocated into the individual nested models that are extracted for predicting individual end uses. However, one can obtain intercept, a*, (not a) for different end use model. See equation (C.9) and the explanation that follows. Intercept a cannot be partitioned any further.

KT: As I say in 7 above, it is possible in theory to decompose the error, but I don't think you'll succeed empirically. That's asking a lot out of the data. Regarding the intercept, you can't decompose it and need to make the assumption that I'd given in 8.

Question 10. How should the resultant coefficients be interpreted (see question 7), when the establishment total metered water use variable (the LHS variable) is logarithmically transformed prior to estimation (i.e., exponential transformation)?

AB: In case of the log formulation, the coefficient on the dummy variable does not have the same clean percent interpretation. It should be interpreted as $(e^b\text{-}1)*100\%$ change on the LHS variable, where b is the coefficient on the dummy variable.

Some addition information and the derivation regarding the question number 10.

How to interpret the dummy coefficient in a semi-log model:

Consider the following model:

$\ln Y = b\,X + d\,DUM$

The interpretation of b is straightforward, in that if the variable x increases by 1 unit the left hand side variable Y increases (decreases) by b*100%. For simplicity, I have excluded the constant term.

The interpretation of d is slightly tricky because we can not take the simple derivative. So, we need to do the following manipulations:

$Y = \exp(b\,X + d\,DUM)$.

Set DUM = 1,

$Y1= \exp(b\,X+d) = \exp(b\,X)\exp(d)$

Set DUM = 0,

$Y0 = \exp(b\,X)$

$Y1\text{-}Y0= \exp(b\,X)\exp(d) - \exp(b\,X) = \exp(b\,X)\,(\exp(d) - 1)$

Divide by Y0 to make it a relative change

$(Y1\text{-}Y0)/Y0 = [\exp(b\,X)\,(\exp(d) - 1)]/\exp(b\,X) = (\exp(d) - 1)$

Change it into the percentage change:

$[(Y1\text{-}Y0)/Y0]*100 = (\exp(d) - 1) * 100.0$.

SS: In a semi-log model

$\ln y = \alpha + \beta x + \Upsilon + \varepsilon$

$\beta = d\ln y/Dx$ = relative change in regressand/absolute change in regressor,

i.e., β measure the relative change (or percent change if relative change is multiplied by 100) in the mean value of y for a unit change in x. Such an interpretation can be applied to a change in any regressor value, provided the regressor is a continuous variable and not a dummy variable.

However, one can obtain the relative change in mean y even for the dummy variable as follows.

Take the antilog (to base e) of the estimated dummy coefficient and subtract 1 from it.

KT: You cannot take a log transformation of the dependent variable and still have the adding up property hold (the first equation in the paper, at the bottom of page 3.) With the log transformation, the impact of each end-use depends on the presence and count for each other end-use. That takes you out of the realm of CDA. To avoid this complication, I'd vote to just stick with the nontransformed dependent variable.

APPENDIX D CI MODEL VALIDITY AND BENCHMARKING PREDICTION RAW TABLES

This appendix contains the audit references, survey number and actual annual water use, for the observations that form the sample sets for each of the five econometric models. It additionally contains predicted annual water use as well as annual predictions for selective end uses and for benchmark estimates: summaries for some listed variables are included in the Benchmarking section tables. The table variable name descriptions are as listed below.

VARIABLE NAME	DESCRIPTION
Observation or Obs.	Observation number.
Survey	Survey number.
Barea (sf)	Building area (in square feet).
Yearly Total	Total water use (in gallons) for a yearly billing period.
Pred Annual	Model prediction for daily water use multiplied by 365.
NetIndoor	Predicted annual use for all indoor end uses.
NetIndrBase	Predicted annual use for base indoor end uses (without cooling and pools).
NetBaseRst	Predicted scaled annual use for all restaurant end uses.
NetIrrigate	Predicted annual use for irrigation and other unspecified outdoor end uses.
NetPool	Predicted annual use for swimming pool and related end uses.
NetCooling	Predicted annual use for all cooling end uses.
IndoorSqft	Predicted indoor water use in gallons per square foot per year.
InBareaToilet	Predicted indoor water use in gallons per square foot per toilet per year.
IndoorEmpl	Predicted indoor water use in gallons per day per employee.
IndoorTrans	Predicted indoor water use in gallons per square foot per daily transaction.
IndrperOccpt	Predicted indoor water use in gallons per day per occupied room.
IndoorPupil	Predicted indoor water use in gallons per school day per student.
GalsperMeal	Predicted gallons per served meal in a restaurant.
GalsperSeat	Predicted gallons per seat per day in a restaurant.
GalsperEmpl	Predicted gallons per employee per day in a restaurant.
OutInchesYr	Predicted irrigation water use on a defined area in inches per year.
TotalCnsmr	Predicted total water use in gallons per transaction (costumer).
TotalperSqFt	Predicted total water use in gallons per square foot per year.
GroundsSqft	Predicted total water use in gallons per square foot (with irrigated area) per year.

Table D.1 Supermarkets

Obs.	Survey	Barea (sqft)	Yearly Total	Pred Annual	NetIndoor	NetIrrigate	IndoorSqft	IndoorTrans	TotalCnsmr	OutInches Yr
1	.	20000	2484856	2495978	2179282	67	109.0	0.049	3.06	.
2	.	41000	2134792	2814941	2277280	141	55.5	0.025	3.45	.
3	.	38646	2359940	2495816	2237053	135	57.9	0.026	3.06	.
4	.	38646	4058648	3421866	2559648	125	66.2	0.030	4.20	.
5	.	38646	3759448	3578377	2476695	139	64.1	0.029	4.39	.
6	.	38646	2003892	2333967	2333832	135	60.4	0.027	2.86	.
7	3271	45000	2459424	2784258	2292654	156	50.9	0.040	5.93	.
8	3272	45100	2600048	2804954	2297993	156	51.0	0.027	4.14	.
9	3273	81230	3299428	2767144	2534091	288	31.2	0.024	5.83	.
10	3274	23292	2382380	2463052	2152620	79	92.4	0.059	4.29	.
11	3278	45000	2422772	2767121	2361782	155	52.5	0.022	3.22	.
12	3284	31500	2543200	2784183	2346185	106	74.5	0.041	4.24	.
13	3308	38646	3312144	2859328	2859199	128	74.0	0.015	1.57	.
14	3323	24400	2324784	2315550	2248270	89	92.1	0.084	5.77	.
15	3324	45000	3027904	3402585	2546121	158	56.6	0.019	3.11	.
16	3329	42000	3895584	3603739	2455094	183	58.5	0.029	4.94	.
17	3355	25000	2647920	2596220	2229607	116	89.2	0.069	5.53	.
18	3356	25000	2404820	2417135	2160480	108	86.4	0.064	4.88	.
19	3357	25800	2195380	2287193	2189362	98	84.9	0.041	3.03	.
20	3407	40000	1668040	2743500	2523447	156	63.1	0.032	3.76	.
21	3447	45000	3359268	3492079	2352565	283492	52.3	0.033	6.09	45
22	3452	25000	2442220	2220477	2220390	87	88.8	0.041	2.84	.
23	3464	44000	2296360	2659884	2478911	168	56.3	0.026	3.40	.
24	3500	55000	6659444	3418460	2471650	207970	44.9	0.035	7.28	56
25	3576	40000	4082584	3210663	2352933	500680	58.8	0.027	4.10	54
26	3592	24400	3039872	2114773	2073147	90	85.0	0.042	2.90	.
27	3640	25000	6473192	3086325	2151263	935062	86.1	0.055	5.38	33
28	3677	40000	2182664	2619360	2316065	139	57.9	0.029	3.59	.
29	3683	49000	3528316	3472352	2473935	164	50.5	0.018	3.33	.
30	3789	65000	3773660	3267095	2590735	245	39.9	0.023	5.22	.
31	3826	25000	3333836	2512346	2114395	31573	84.6	0.033	2.68	25
32	3851	42649	2431000	2320569	2280101	154	53.5	0.005	0.58	.
33	3991	80000	6549488	2649180	2538937	294	31.7	0.026	5.98	.

Table D.2 Hotels and Motels

Observation	Survey	Barea (sqft)	Yearly Total	Pred Annual	NetIndoor	NetIrrigate	TotalperSqFt	OutInchesYr	IndrperOccpt
1	.	170634	14289044	9660248	9660276	-28	57	.	143.9
2	.	170634	5721452	5706496	5645553	60943	33	33	107.4
3	.	468000	37312484	31563847	30826486	737362	67	79	242.4
4	.	950000	73850040	.	.	.	.	.	.
5	.	170634	29286444	28246788	28246887	-99	166	.	236.6
6	.	20000	3300924	2242022	2213237	28785	112	9	148.6
7	.	32000	2499816	3461669	3425226	36443	108	6	381.5
8	.	60000	.	.	.	.	.	.	.
9	.	170634	41289600	28079885	28079975	-90	165	.	241.2
10	.	170634	12599312	17741504	16654071	1087433	104	47	219.0
11	.	12850	1668040	2868410	2849918	18492	223	4	464.8
12	.	40000	3086248	4275078	3983040	292038	107	16	158.2
13	.	170634	307932152	304816032	46626209	258189823	1786	102	282.8
14	.	170634	46278012	48117281	48117422	-141	282	.	276.7
15	.	170634	29434548	26852640	25549603	1303037	157	48	330.1
16	.	170634	40714388	40439614	19311395	21128218	237	78	153.9
17	.	370000	.	40417178	40417290	-112	109	.	289.2
18	.	170634	.	.	.	.	.	.	.
19	.	170634	17308720	12080905	11327234	753671	71	57	123.1
20	.	170000	17788936	12514669	12358277	156392	74	36	213.8
21	.	300000	24523928	20249126	18344586	1904541	68	51	223.4
22	.	285000	14962992	13848354	13536929	311425	49	64	131.0
23	.	170634	19275960	20712808	19340139	1372669	121	44	272.3
24	.	27000	5668344	4263389	4240706	22683	158	18	144.5
25	3262	55000	8927380	5131635	5111389	20246	93	27	117.1
26	3269	80000	23838012	19930639	19424488	506151	249	41	296.6
27	3287	45000	3312144	4974971	4942459	32512	111	11	282.1
28	3289	60000	5843376	.	.	.	.	.	.
29	3294	60000	8239220	.	.	.	.	.	.
30	3310	50000	1769768	3729414	3729408	6	75	.	256.1
31	3320	55000	3343560	4093802	3931623	162178	74	12	206.2
32	3374	261000	3044360	11647123	11580238	66885	45	18	401.4
33	3375	417000	29810792	27620735	27620803	-68	66	.	201.7
34	3408	65000	7287016	6392710	5559450	833260	98	30	116.0
35	3426	68411	3509616	.	.	.	.	.	.
36	3457	65000	7506180	5750651	5274502	476149	88	25	128.5
37	3462	45000	7569760	6887559	6651209	236351	153	22	184.9
38	3465	200000	5935380	10097093	7092067	3005026	50	24	182.4
39	3490	170634	7192768	11970228	11639078	331150	70	53	135.8
40	3504	170634	22820732	26522883	25234670	1288213	155	65	242.3
41	3514	170634	12386880	7920683	7914768	5916	46	32	154.6
42	3540	13000	2404072	3729145	3714042	15104	287	8	285.3
43	3550	170634	11399520	10740817	8953054	1787763	63	36	154.9
44	3586	170634	4095300	2874391	2706501	167890	17	8	218.1
45	3591	170634	9099420	13803645	13629865	173780	81	28	303.1
46	3597	1500000	103974244	101341748	99718983	1622765	68	260	237.5
47	3599	186400	18263916	21633373	21324395	308978	116	50	266.7
48	3647	18000	3823028	3181829	3123627	58202	177	9	207.5
49	3658	150000	17819604	24761996	21821625	2940371	165	50	272.5

(continued)

Table D.2 (Continued)

Observation	Survey	Barea (sqft)	Yearly Total	Pred Annual	NetIndoor	NetIrrigate	TotalperSqFt	OutInchesYr	IndrperOccpt
50	3659	200000	18107584	12753829	11387123	1366707	64	49	144.9
51	3660	75000	32155772	27588219	24902098	2686121	368	62	250.8
52	3662	110000	17169592	6551167	5753439	797727	60	16	223.0
53	3663	180000	10694156	8553654	7702242	851412	48	27	174.8
54	3664	41000	5718460	4129588	4094312	35276	101	11	224.3
55	3665	80000	6001952	5546845	5134181	412664	69	22	144.3
56	3671	18000	5055732	3907457	3566217	341241	217	22	101.0
57	3673	16000	3840232	2854859	2810944	43915	178	14	123.7
58	3675	56310	2977788	3206461	3090066	116394	57	17	112.9
59	3679	20000	2338248	3358051	3342639	15412	168	8	251.6
60	3744	170634	6245800	4644790	3595277	1049512	27	21	107.3
61	3749	75000	7147888	8182848	7674969	507879	109	27	175.2
62	3811	20000	3928496	3410862	3324407	86455	171	7	282.4
63	3817	87000	26788872	35133082	34936469	196613	404	90	240.3
64	3818	70000	2163216	4505387	4473952	31435	64	6	495.2
65	3878	170634	3813304	2808137	2407067	401070	16	16	92.8
66	3903	170634	2256716	2159395	2159388	7	13	.	199.2
67	3926	170634	4420680	4159242	3963706	195536	24	14	172.4
68	3931	170634	11456368	6718846	5567968	1150878	39	42	82.3
69	3933	170634	11222992	5519797	5519806	-9	32	.	82.5
70	3937	660000	17480760	15486721	13587954	1898767	23	35	240.6
71	3938	170634	10543808	8200727	7236385	964342	48	33	134.9
72	3939	170634	15593556	12128079	10329846	1798233	71	51	125.0
73	3940	170634	3400408	2942063	2602562	339501	17	18	89.1
74	3945	170634	7539840	9544319	9377614	166705	56	28	207.2
75	3946	170634	8212292	7128375	6944182	184194	42	32	136.4
76	3947	65000	4211240	3747153	3628339	118814	58	22	102.7
77	3948	170634	8581056	4781868	4781876	-8	28	.	156.0
78	3951	170634	2728704	4874788	4701476	173312	29	19	157.3
79	3953	170634	7028208	9450286	9318041	132245	55	21	272.3
80	3957	170634	6636256	5412317	5374779	37538	32	15	224.1
81	3958	170634	6331820	8095508	7966216	129292	47	22	223.8
82	3959	170634	5481344	3554017	3430217	123800	21	20	107.1
83	3960	44000	4832080	6580459	6574057	6402	150	29	138.5
84	3964	350000	23006984	27276620	27276707	-87	78	.	233.5
85	3978	170634	26686396	33387157	30406367	2980790	196	86	218.8
86	3981	170634	12716000	37386516	8133893	29252623	219	38	131.1
87	3996	170634	1983696	2918273	2909462	8811	17	7	255.5
88	4016	170634	52192448	57875423	57875627	-203	339	.	226.5
89	4020	170634	146452416	142218755	88732221	53486535	833	245	224.4
90	4021	170634	21129504	13581631	6667383	6914248	80	53	77.5
91	4023	170634	38533968	.	.	.	.	.	.
92	4026	170634	4507448	6523033	6184452	338581	38	27	141.2
93	4035	170634	8711208	6412985	6412998	-13	38	.	78.4
94	4040	170634	13487188	.	.	.	.	.	.
95	4054	27000	3163292	3510866	3508897	1970	130	11	207.2
96	4056	170634	7997616	16519299	16222429	296870	97	40	253.4
97	4100	110000	3014440	4614049	4612125	1925	42	10	278.0
98	4102	170634	3748976	4149266	4074207	75059	24	15	167.9
99	4118	440000	23379488	27389945	25065897	2324048	62	56	275.1
100	4145	170634	59645520	67144978	18749123	48395855	394	178	65.2

Table D.3 Office Buildings

Obs.	Survey	Barea (sqft)	Yearly Total	Pred Annual	NetIndrBase	NetCooling	NetIrrigate	TotalperSqFt	IndoorEmpl	InBareaToilet
1	3256	130000	4293520	6200312	3411484	1112748	1676080	48	26.7	0.57
2	3265	255000	6769400	9948838	7475117	2174422	299300	39	17.1	0.37
3	3267	86000	5089392	3761199	2577962	734287	448950	44	14.1	0.83
4	3312	174848	4820112	2992069	2992073	-4	0	17	273.3	1.32
5	3327	39000	3778896	4999884	2989048	5526	2005310	128	101.1	2.84
6	3345	300000	3267264	5658220	3100991	2557230	0	19	17.0	0.16
7	3358	24000	2787048	4030774	2230025	4950	1795800	168	117.5	6.64
8	3381	396000	10472000	11803881	7828120	3377161	598600	30	17.9	0.18
9	3389	174848	13987600	6849244	4908661	1491634	448950	39	19.2	1.87
10	3402	350000	16435056	10759935	4775240	2991695	2993000	31	23.3	0.19
11	3509	60000	2992000	3680702	1718156	515430	1447116	61	21.9	1.10
12	3523	20000	2175184	2690887	1010187	4620	1676080	135	65.9	6.31
13	3529	150000	5618228	5979918	2240277	1285381	2454260	40	18.9	0.41
14	3568	174848	3445288	4442414	4292378	386	149650	25	30.2	0.29
15	3618	295000	8020056	8980635	6466090	2514545	0	30	11.8	0.27
16	3686	95637	8386576	6903121	1995990	826475	4080656	72	25.8	0.38
17	3690	230000	7942264	9917170	2335027	1976014	5606128	43	18.3	0.30
18	3772	128000	7643812	5796336	3241049	1095091	1460195	45	16.1	0.79
19	3780	95000	3017432	3137596	1126761	5525	2005310	33	30.9	1.08
20	3830	50000	2728704	1870378	1270137	1642	598600	37	26.8	1.81
21	3859	174848	20780188	14140575	4816904	1511941	7811730	81	15.5	0.32
22	3880	174848	2468400	3423877	1623130	4947	1795800	20	43.6	0.23
23	3883	174848	3590400	4402973	1821908	7085	2573980	25	20.4	0.29
24	3886	174848	18664844	8445613	6955256	1490357	0	48	14.7	0.27
25	3888	174848	11632896	8110677	6590301	1490446	29930	46	15.1	0.18
26	3889	174848	7961712	7559493	6659117	2476	897900	43	3040.7	2.12
27	3894	174848	7072340	11347325	9851004	1490335	5986	65	14.2	0.37
28	3895	174848	4810388	.	.	.	.	.	.	.
29	3896	40000	2813976	942800	942807	-7	0	24	34.4	2.36
30	3898	140500	5052740	6492997	2744306	1204641	2544050	46	16.7	0.40
31	3900	80000	8823408	6035783	2082498	690915	3262370	75	16.8	1.45
32	3905	174848	2399584	2085405	339860	1491140	254405	12	93.1	.
33	3907	25000	1391280	1725387	1437265	213297	74825	69	19.7	3.83
34	3908	280000	2079440	2421931	1821697	1634	598600	9	20.0	0.19
35	3916	174848	2491588	3452726	1913083	1490559	49085	20	20.8	0.24
36	3923	174848	7434372	10405435	3589602	1505054	5310779	60	15.8	0.32
37	3924	548900	14674264	15096285	2584088	4700467	7811730	28	17.7	0.08
38	3925	174848	4934556	3571708	1661109	1491580	419020	20	18.2	0.59
39	3928	174848	4532880	5494986	3403236	5748	2086001	31	106.0	0.88
40	3930	300000	7266820	8375188	5487851	2558106	329230	28	15.0	0.15
41	3949	174848	5583820	7180847	5390345	1491202	299300	41	14.8	0.44
42	3952	174848	6084232	5471809	3531218	1491641	448950	31	16.7	0.20
43	3954	174848	7723100	11384390	5392123	1502767	4489500	65	15.6	0.17
44	3962	324000	6687120	10729623	7967875	2761747	0	33	14.6	0.13
45	3966	104000	6348276	5713145	2845830	891935	1975380	55	15.6	1.37
46	4033	174848	5692280	6339077	4148209	5979	2184890	36	14.9	0.85
47	4034	174848	1922360	4193369	1192121	8248	2993000	24	22.5	0.57
48	4050	174848	8563104	10875808	2782607	1508601	6584600	62	63.5	0.69
49	4094	174848	3111680	3524850	2924611	1639	598600	20	46.6	1.86
50	4130	174848	224400	2328295	2328308	-13	0	13	37.5	0.55

Table D.4 Restaurants

Observation	Survey	Barea (sqft)	Yearly Total	Pred Annual	NetBaseRst	GroundsSqft	GalsperMeal	GalsperSeat	GalsperEmpl
1	.	3000	3925504	.	.	.	.	.	.
2	.	4000	1908148	.	.	.	.	.	.
3	.	10654	2480368	.	.	.	.	.	.
4	.	4000	714340	1639808	1639944	410	15.7	23.6	204
5	.	5300	840004	.	.	.	.	.	.
6	.	6642	.	.	1490848	.	6.1	21.5	89
7	.	5200	1523676	.	.	.	.	.	.
8	.	7000	3312892	.	.	.	.	.	.
9	.	7000	3789368	2750639	2751000	393	11.0	39.7	89
10	.	10000	4179824	3125463	3125999	313	8.6	45.1	103
11	.	10654	1666544	2808820	2809166	264	11.5	40.5	308
12	.	5300	1750320	2098192	2098406	396	13.4	30.3	155
13	.	10654	.	.	.	.	.	.	.
14	.	4000	641784	1450708	2278706	363	9.4	32.9	184
15	.	2500	1697960	2060873	2061221	824	8.5	29.7	332
16	3259	10654	1742840	2191110	2191422	173	10.0	34.3	200
17	3268	10654	6058800	1585229	1585403	149	11.7	19.3	174
18	3283	8000	1534896	2442996	2443373	305	9.2	33.1	156
19	3293	4000	1223728	1193137	1193344	239	8.2	24.4	117
20	3296	4000	2853620	1519227	1519407	276	11.9	29.7	64
21	3297	4000	2744412	3064372	3064800	486	10.5	56.0	187
22	3306	4000	1635876	2038243	2038386	510	18.6	29.4	160
23	3307	4000	1056924	1766660	1766920	411	9.7	32.3	323
24	3314	4000	4772988	2571743	2572135	643	9.5	40.0	176
25	3321	5120	1849056	2456047	2456471	429	8.4	37.4	96
26	3338	5000	2280652	2596349	2596696	371	10.7	37.4	145
27	3340	3000	357544	1274583	1274645	425	22.2	18.4	194
28	3341	37000	822800	1229008	1477379	33	20.2	27.9	253
29	3352	10000	2496076	3014114	3014413	167	13.8	33.0	184
30	3354	5000	3650240	4468122	4469050	745	7.1	55.7	136
31	3361	6000	3137112	1910486	1910573	174	26.2	27.5	116
32	3366	4500	2992000	2220864	2221100	296	13.3	36.7	94
33	3372	4500	1398760	1827628	1827841	406	11.7	26.4	185
34	3377	2200	1720400	.	.	.	.	.	.
35	3382	60000	1454112	3049852	3050204	41	12.5	44.0	56
36	3387	5600	5132028	3482249	3483063	441	6.4	53.0	147
37	3455	10000	1484032	1839336	1839478	184	16.8	26.5	336
38	3458	14000	2541704	2303545	2303838	105	11.0	33.2	263
39	3460	25000	5035536	2519653	2520074	76	8.6	36.3	690
40	3467	3000	3457256	4336123	2061127	1445	43.4	29.7	403
41	3468	5000	7685700	6904928	2176336	1381	42.6	31.4	239
42	3470	20000	3654728	2860329	2860473	68	26.1	41.2	104
43	3512	10654	3081012	3611003	3611536	339	9.9	52.1	165
44	3513	12000	2692052	3426803	3427335	286	9.4	49.4	235
45	3521	3000	1484032	1676114	5401921	186	4.9	77.9	548
46	3528	10654	2822952	2966150	1696282	97	19.0	24.5	155
47	3536	20000	2042788	2663438	1626805	70	22.3	23.5	637
48	3543	10654	7772468	8539199	1935931	802	19.6	27.9	177

(continued)

Table D.4 (Continued)

Observation	Survey	Barea (sqft)	Yearly Total	Pred Annual	NetBaseRst	GroundsSqft	GalsperMeal	GalsperSeat	GalsperEmpl
49	3544	10000	3815548	3592934	3593411	225	10.9	51.8	246
50	3553	10000	4773736	2921999	2922374	292	11.2	42.1	113
51	3556	18000	2298604	2340145	2340491	94	9.6	33.7	427
52	3559	14000	1782484	2264198	2264543	142	9.3	32.7	1034
53	3561	11000	2166208	2201405	2201713	138	10.1	31.7	603
54	3563	15000	2296360	2800645	2800993	112	11.5	40.4	118
55	3569	3000	1406988	1396020	2224016	107	9.1	32.1	381
56	3578	10654	1979208	3425097	3425743	200	7.8	49.4	142
57	3587	20000	2887280	2775428	2775642	139	17.7	40.0	253
58	3593	55000	2671856	2616124	2616298	33	20.1	37.7	179
59	3620	10000	2553672	5223961	1768335	522	7.3	25.5	138
60	3621	10000	3541780	4014472	4015097	365	9.2	36.8	275
61	3623	10000	3599376	3277382	3277972	218	8.2	47.3	180
62	3628	10000	1878228	2629342	2629689	202	10.8	37.9	160
63	3629	30000	2645676	2349356	2349704	67	9.7	33.9	99
64	3630	8000	2255968	3084318	3084665	220	12.7	44.5	192
65	3632	7000	3077272	2049128	2049295	256	16.0	28.1	281
66	3633	11000	1715164	2712081	2712429	209	11.1	39.1	146
67	3639	5000	3273248	2648520	5309803	241	6.8	76.6	485
68	3646	9400	2137784	2322918	2323094	106	17.8	33.5	84
69	3672	6000	1965744	2409869	2410298	321	8.1	34.8	169
70	3681	5000	5141004	3901909	2050802	780	15.7	29.6	194
71	3757	25000	6797076	7667643	2610841	170	10.7	37.6	193
72	3765	10000	1946296	2170091	2998088	114	12.3	43.2	228
73	3766	15000	2406316	2695731	2696075	108	11.1	35.7	205
74	3776	12000	2732444	2370325	2370672	88	9.7	34.2	130
75	3787	5500	2244748	2378593	2378768	227	18.2	34.3	93
76	3799	10000	3283720	2749447	2749750	115	12.6	33.0	157
77	3807	10000	12574628	10285247	3501016	1029	9.6	50.5	200
78	3819	20000	1364352	1339849	1340168	45	6.3	36.7	61
79	3873	5000	2094400	3034364	3034857	379	9.0	43.8	151
80	3906	10654	2710752	2243026	2243373	211	9.2	32.3	162
81	3913	10654	1880472	.	.	.	.	.	.
82	3914	10654	1021020	2169346	2169692	130	8.9	31.3	198
83	3915	10654	2714492	2399596	2399944	225	9.9	34.6	120
84	3990	10654	4170100	3090017	3090440	235	10.6	44.6	94
85	4030	10654	2457928	3342702	3343052	314	13.7	48.2	86
86	4042	10654	3463240	3360109	3360456	61	13.8	48.5	142
87	4048	10654	3177504	2674585	2674933	251	11.0	38.6	113

Table D.5 Schools

Obs.	Survey	Barea (sqft)	Yearly Total	Pred Annual	NetIndrBase	NetIrrigate	NetPool	NetCooling	Indoor Pupil	Indoor Empl	Total per SqFt
1	.	69700	8003600	.	4179517	.	.	.	21.1	157	.
2	.	90800	15307820	24983884	8387884	16596001	-155601	-155601.44	30.3	255	275
3	.	391130	11968000	.	17882034	.	.	.	34.4	306	.
4	.	139707	35167220	.	.	.	.	.	.	.	.
5	.	139707	46094004	.	.	.	.	.	.	.	.
6	.	139707	17309468	.	.	.	.	.	.	.	.
7	.	139707	7106748	.	.	.	.	.	.	.	.
8	.	150000	2280652	.	.	.	.	.	.	.	.
9	.	160000	3850704	.	.	.	.	.	.	.	.
10	.	34540	11758560	7528970	3126986	4401983	-41162	-41161.65	20.0	182	218
11	.	139707	25215828	.	.	.	.	.	.	.	.
12	.	139707	33007744	.	.	.	.	.	.	.	.
13	.	139707	10344092	.	.	.	.	.	.	.	.
14	.	139707	2830432	.	.	.	.	.	.	.	.
15	3260	384000	4305488	5583129	2238161	3344968	-31282	-31282.01	20.3	153	15
16	3261	75000	2809488	4343354	2603918	1739436	-16214	-16213.65	17.7	119	58
17	3300	174240	2276912	4445525	3642611	802914	-7386	-7385.64	16.1	200	26
18	3305	139707	2080188	2622907	2194639	428268	-3892	-3892.42	34.5	120	19
19	3317	114400	9566172	9281621	6404897	2876724	-26851	-26850.99	38.6	251	81
20	3318	22000	5613740	4256307	3556797	699511	-6423	-6422.72	43.5	162	193
21	3319	187308	10386728	14185818	9251469	2739349	2169443	-25556.91	25.7	253	76
22	3344	96400	1352384	8305059	3059669	5245391	-49110	-49109.52	.	105	86
23	3367	92914	3973376	2903562	1659160	1244402	-11563	-11562.7	2.3	284	31
24	3376	139707	8856320	8107327	4702772	39013	36987	3402528.69	17.4	107	58
25	3383	500000	24325708	21965223	6390686	13379538	2069538	-125462.3	18.1	175	44
26	3385	139707	20899868	21629697	3178891	14012111	2088444	2137138.39	15.2	87	155
27	3391	143748	19107660	20998556	5758479	13045077	2072702	-122298.24	16.1	149	146
28	3392	130680	24009304	22400163	4818684	15386479	2050729	-144271.07	15.7	132	171
29	3393	174240	19470440	21070634	5295381	13580253	2067678	-127322.07	19.2	161	121
30	3394	130000	16898816	22853552	4335512	16323040	2041940	-153060.24	14.6	125	176
31	3395	85971	11363616	11133680	3507284	7626396	-71454	-71453.79	28.7	120	130
32	3396	74519	8334216	12877559	4047014	8830546	-82754	-82754.25	16.0	158	173
33	3397	132967	23280752	19779196	6399633	13379563	-125437	-125437.14	19.1	169	149
34	3398	80000	9709040	13899577	4062227	9837349	-92202	-92202.04	19.3	159	174
35	3399	71000	9304372	11945148	4422443	7522705	-70481	-70481.43	19.5	173	168
36	3400	234000	18710472	18522665	7068969	9258696	2108236	-86764.07	18.3	149	79
37	3450	80000	3763188	4129333	2791263	1338070	-12430	-12429.77	25.8	118	52
38	3453	76500	5046756	6500388	4314035	2186353	-20364	-20363.93	39.9	236	85
39	3454	80000	7773216	7905147	4988274	2916873	-27217	-27217.39	18.5	217	99
40	3503	87000	7824828	9709943	3298937	6411006	-60050	-60050.25	18.1	135	112
41	3508	76473	42668912	11292289	5347540	5944749	-55685	-55684.53	11.8	81	148
42	3545	160000	20228912	13995186	3772385	8027801	2119801	-75199.01	14.4	98	87
43	3546	50000	4802908	4631577	2731570	1900007	-17703	-17702.78	21.6	159	93
44	3547	139707	6408864	7363420	3550150	3813270	-35656	-35655.5	26.8	174	53
45	3552	210000	5085652	7492260	4481756	3010504	-28121	-28121.05	51.2	192	36
46	3570	355000	10875920	15473950	7374447	8099503	-75884	-75883.86	20.7	289	44
47	3571	53000	4235924	6787004	2692777	4094227	-38303	-38302.82	19.1	134	128

(continued)

Table D.5 (Continued)

Obs.	Survey	Barea (sqft)	Yearly Total	Pred Annual	NetIndrBase	NetIrrigate	NetPool	NetCooling	Indoor Pupil	Indoor Empl	Total per SqFt
48	3572	33049	4864992	5949002	1935052	4013949	-37551	-37550.84	19.1	115	180
49	3573	81760	10457788	8274629	3056526	5218103	-48847	-48846.55	13.1	105	101
50	3574	29000	2621740	3641679	1607890	2033789	-18971	-18971.42	22.1	176	126
51	3575	37000	2200616	3782557	2605052	1177505	-10935	-10935.13	24.9	246	102
52	3577	50000	3211912	3699636	1358121	2341515	-21860	-21860.03	37.7	207	74
53	3588	80000	9325316	6858543	2831226	4027318	-37687	-37687.48	18.1	172	86
54	3589	180000	30220696	22953908	7346765	10521343	2128423	2824223.15	12.1	201	128
55	3590	155000	14152160	19029010	5180400	11653610	2085755	-109244.91	14.3	142	123
56	3653	71000	16942948	9297875	3665014	5632861	-52744	-52743.66	16.7	165	131
57	3654	35000	15119324	5983996	1970050	4013946	-37554	-37553.53	15.2	102	171
58	3655	82500	12525260	13770819	4351571	9419248	-88272	-88272.03	15.4	145	167
59	3656	35000	8385828	6268982	1947308	4321675	-40440	-40440.38	11.2	86	179
60	3666	32500	13655488	7279966	3078675	4201291	-39279	-39278.59	14.8	187	224
61	3668	35000	11125752	7355600	2752926	4602674	-43046	-43046.38	19.3	222	210
62	3669	43000	11869264	7593808	3847417	3746391	-35009	-35009.17	18.1	224	177
63	3670	64900	16242072	11776894	5220816	6556077	-61373	-61372.69	27.6	223	181
64	3682	174000	4801412	7816004	7039856	776148	-7142	-7142.08	37.3	103	45
65	3684	80000	6742472	4964592	2288576	2676016	-24984	-24984.19	17.4	112	62
66	3687	224652	2034560	18885440	6521960	10168480	2099680	-95320.02	14.5	108	84
67	3695	139707	22748924	27277810	20310067	5845895	-42285	1079562.6	33.9	185	195
68	3728	34000	5538940	5530662	2051888	3478773	-32527	-32526.77	17.3	125	163
69	3729	63000	5074432	6281545	1799313	4482231	-41944	-41943.57	17.6	117	100
70	3730	128000	9865372	10621412	2593625	8027787	-75213	-75212.94	17.6	129	83
71	3731	35000	5935380	4595065	1367337	2946678	-24422	256627.82	11.2	85	131
72	3732	40000	5773812	5823821	2077457	3746363	-35037	-35036.75	15.4	102	146
73	3733	139707	17140420	22263419	7545895	14717524	-137976	-137975.99	16.8	133	159
74	3734	139707	6970612	7174556	1929697	5244859	-49101	-49101.04	18.8	176	51
75	3735	139707	9287168	12010116	3267865	8742251	-81916	-81915.74	14.5	132	86
76	3794	139707	46074556	39969033	16656581	23312453	-218659	-218659.43	34.7	351	286
77	3796	139707	71165468	71165468	22327189	26275778	17878389	4290665.89	.	175	509
78	3813	60000	4903888	5680799	997904	4682895	-43855	-43855.17	7.3	48	95
79	3814	160000	7655780	6829957	1585126	5244831	-49129	-49128.7	14.0	89	43
80	3815	260000	20419652	21824279	6036433	15787845	-148055	-148054.51	23.7	145	84
81	3840	209593	30403208	18263252	7852414	6020838	4333588	-56412.13	23.4	207	87
82	3841	186557	25702776	28894271	8764723	12743442	4303692	2909796.96	19.0	162	155
83	3842	57147	12536480	9457265	2700559	6756707	-63318	-63318.19	16.4	157	165
84	3843	282000	25044536	22891407	8654007	9847400	4297720	-92279.83	15.7	148	81
85	3845	384000	44983224	36202606	14687515	19320091	2013871	-181129.49	25.0	201	94
86	3847	200000	25233780	27927824	12414634	9517190	4318640	1534639.57	20.7	184	140
87	3855	150000	20000024	23365511	11001989	10168522	2099722	-95278.48	28.4	152	156
88	3856	65994	10834780	10219887	3530039	6689849	-62651	-62651.28	10.1	129	155
89	3857	200000	25007884	24583916	8849550	15734366	-147514	-147513.67	14.8	158	123
90	3874	139707	12540220	9925136	3235290	6689846	-62654	-62653.8	19.3	177	71
91	3882	139707	6296664	4912647	3761893	1150754	-10676	-10675.98	25.3	112	35
92	3911	139707	6807548	12746272	6324025	6422247	-60153	-60153.29	35.4	160	91
93	3912	139707	5532208	3555571	1548551	2007020	-18730	-18730.11	19.3	90	25
94	3917	139707	2632960	2695937	2401485	294451	-2659	-2658.72	25.8	132	19
95	3918	139707	6771644	8078911	7195750	883160	-8170	-8169.69	19.8	124	58

(continued)

Table D.5 (Continued)

Obs.	Survey	Barea (sqft)	Yearly Total	Pred Annual	NetIndrBase	NetIrrigate	NetPool	NetCooling	Indoor Pupil	Indoor Empl	Total per SqFt
96	3919	139707	2315060	2757387	2462935	294452	-2658	-2657.74	14.4	112	20
97	3920	139707	3076524	7993069	7404254	588815	-5405	-5404.52	43.3	107	57
98	3921	139707	4723620	6293502	5410348	883154	-8176	-8176.37	29.1	148	45
99	3922	139707	2156484	4688437	4393977	294460	-2650	-2649.94	30.8	93	34
100	3942	139707	5572600	5612107	2989617	2622490	-24490	-24489.66	20.7	126	40
101	3943	139707	5931640	6845006	3088360	2634799	-12181	1109665.87	23.1	101	49
102	3944	440000	5101360	4328366	2749473	1578893	-14697	-14696.81	14.5	116	10
103	3950	139707	4387768	8385872	7457223	928649	-8598	-8598.18	33.1	146	60
104	3955	139707	4338400	5219460	2663868	2555592	-23863	-23863.14	24.7	135	37
105	3956	139707	4532880	5194931	2749473	1323611	121	1121967.9	18.2	116	37
106	3998	139707	11519200	9069301	4989500	4079800	-38144	-38144.43	10.7	114	65
107	3999	139707	2591820	2053199	715173	1338027	-12473	-12473.41	5.6	53	15
108	4000	139707	2069716	1770596	967747	802849	-7451	-7450.91	9.4	66	13
109	4001	139707	2013616	852462	619256	233205	-2106	-2105.85	4.6	45	6
110	4002	152460	2805000	2865213	607532	1033427	3941	1228194.82	6.3	42	19
111	4003	139707	3702600	2972636	958143	2014494	-18819	-18819.25	7.3	46	21
112	4005	139707	27593720	20529420	5959066	14570354	-136591	-136590.7	17.0	163	147
113	4006	139707	14804416	16926208	4860156	8749204	2125440	1052286.7	16.6	121	121
114	4009	139707	2980780	4719433	2711472	886113	4237	1126084.07	24.5	124	34
115	4010	139707	1799688	1395187	1385029	10159	30	30.12	25.6	190	10
116	4011	174240	3141600	3549357	969161	1181049	4493	1403640.69	5.5	53	20
117	4018	139707	51391340	49343096	33363801	12613753	-80947	3284595.01	40.4	254	353
118	4043	139707	2398088	4120304	2708646	1411659	-13119	-13118.66	18.3	186	29
119	4078	139707	3493160	5527294	4098658	306788	9678	1131525.55	19.5	107	40
120	4079	139707	4142424	5484285	3614131	748307	5532	1127379.23	19.5	132	39
121	4080	139707	5132028	4837904	3071688	1766216	-16444	-16443.66	21.3	140	35
122	4084	139707	9256500	9017098	3173258	4721993	-31767	1090080.48	14.0	97	65
123	4085	139707	4859008	6239235	2750180	2367208	-9672	1112175.37	20.0	108	45
124	4086	139707	16353524	9255226	4615534	3517845	-20465	1101381.96	13.6	126	66
125	4087	139707	6821760	6275976	2930994	3344981	-31269	-31268.53	20.8	107	45
126	4089	139707	3900820	3583292	1251942	2331350	-21762	-21761.61	19.1	98	26
127	4090	139707	2468400	3758402	2853030	905373	-8376	-8375.57	21.1	104	27
128	4091	139707	4237420	5467603	2567246	1778510	-4150	1117697.63	18.4	141	39
129	4097	139707	4455088	7045902	2379464	3544591	-20729	1101117.91	16.5	109	50
130	4098	139707	4645828	11361372	3162758	7076768	-53872	1067974.73	18.5	108	81
131	4109	139707	2990504	2243914	1387540	856374	-7947	-7946.5	8.4	67	16
132	4110	139707	2280652	4166036	3463517	702518	-6494	-6494.2	17.5	71	30
133	4111	139707	3459500	5523404	2150918	1177486	2184046	-10954.47	6.5	56	40
134	4112	139707	1861772	1569919	981133	588785	-5435	-5434.51	3.9	38	11
135	4113	139707	6059548	.	.	.	.	.	.	.	.
136	4127	139707	14574032	13468793	5858883	6488062	-48358	1073489.55	12.7	92	96
137	4128	139707	14929332	11153357	4894775	5136735	-35680	1086167.27	9.4	89	80
138	4154	131384	11954092	20243757	7399365	12844392	-120408	-120407.91	26.5	236	154

APPENDIX E CI MODEL DATABASE AND AUDIT TABLES

This appendix contains excerpted audit and billing data that was used for efficiency benchmarks.

Table E.1 Benchmarking measures for audit data Supermarkets

Case	Building Area	Water Use (gallons)	Q-cool-irr (Net indoor)	Qindoor/sf Gal/day	Qcool/ft, gal/day
1	45,000	2,459,424	984,368	0.060	0.090
2	45,100	2,600,048	1,500,488	0.091	0.067
3	81,230	3,299,428	1,693,472	0.057	0.054
4	32,292	2,382,380	886,380	0.075	0.127
5	45,000	2,422,772	393,448	0.024	0.124
6	31,500	2,543,200	1,119,756	0.097	0.124
7	–	3,312,144	1,766,028	–	–
8	24,400	2,324,784	813,824	0.091	0.170
9	45,000	3,027,904	2,277,660	0.139	0.046
10	42,000	3,895,584	1,135,464	0.074	0.180
11	25,000	2,647,920	1,077,120	0.118	0.172
12	25,000	2,404,820	983,620	0.108	0.156
13	25,800	2,195,380	1,207,272	0.128	0.105
14	40,000	1,668,040	917,796	0.063	0.051
15	45,000	3,359,268	2,351,712	0.143	0.039
16	25,000	2,442,220	–	0.268	–
17	44,000	2,296,360	1,240,184	0.077	0.066
18	55,000	6,659,444	4,648,820	0.232	0.093
19	20,000	3,665,200	–	–	–
20	40,000	4,082,584	1,026,584	0.070	0.280
21	24,400	3,039,872	1,003,068	0.113	0.229
22	25,000	6,473,192	3,431,076	0.163	0.333
23	40,000	2,182,664	1,265,616	0.087	0.063
24	49,000	3,528,316	2,046,528	0.114	0.083
25	65,000	3,773,660	981,376	0.041	0.118
26	20,000	2,531,232	–	–	–
27	25,000	3,333,836	1,608,948	0.176	0.182
28	42,649	2,431,000	655,996	0.042	0.114
29	80,000	6,549,488	–	–	–
30	20,000	2,484,856	1,258,136	0.172	0.168
31	41,000	2,134,792	788,392	0.053	0.090
32	–	2,359,940	565,965	–	–
33	–	4,058,648	1,430,648	–	–
Mean	35,405.182	3,644,777.3	1,274,064	0.087	0.101
Std. Dev.	16,078.061	1,251,632.138	880,136.937	0.058	0.073
Min	20,000	1,668,040	393,448	0.024	0.039
Max	81,230	6,549,488	4,648,820	0.268	0.333

Table E.2 Benchmarking measures for audit data Office buildings

Case	Building Area	Water Use (gallons)	Q-cool-irr (Net indoor)	Qindoor/ sf/days	Qcool/ sf/days
1	130,000	4,293,520	1,847,560	0.038936986	0.014502845
2	255,000	6,769,400	3,045,856	0.032724749	0.037819909
3	86,000	5,089,392	3,256,792	0.103752533	0.03693533
4	–	4,820,112	4,820,112	–	–
5	39,000	3,778,896	418,880	0.029426063	0
6	300,000	3,267,264	2,163,964	0.019762228	0.010075799
7	24,000	2,787,048	1,038,224	0.118518721	0
8	396,000	10,472,000	4,488,000	0.031050228	0.03674277
9	–	13,987,600	3,374,228	–	–
10	350,000	16,435,056	3,617,328	0.028315679	0.041161957
11	60,000	2,992,000	736,032	0.033608767	0.032447489
12	20,000	2,175,184	86,768	0.011886027	0
13	150,000	5,618,228	1,266,364	0.023129936	0.036204566
14	–	3,445,288	1,757,052	–	–
15	295,000	8,020,056	4,711,652	0.043758087	0.030725832
16	95,637	8,386,576	1,939,564	0.055562951	0.072855393
17	230,000	7,942,264	1,373,328	0.01635888	0
18	128,000	7,643,812	2,890,272	0.061863699	0.066106421
19	95,000	3,017,432	411,400	0.011864456	0
20	50,000	2,728,704	2,728,704	0.149518027	0
21	–	20,780,188	6,011,676	–	–
22	–	2,468,400	-1,488,520	–	–
23	–	3,590,400	-418,880	–	–
24	–	18,664,844	12,492,348	–	–
25	–	11,632,896	11,632,896	–	–
26	–	7,961,712	7,961,712	–	–
27	–	7,072,340	4,316,708	–	–
28	–	4,810,388	4,810,388	–	–
29	40,000	2,813,976	2,514,776	0.172244932	0
30	140,500	5,052,740	2,934,404	0.057220377	0.041307191
31	80,000	8,823,408	2,459,424	0.084226849	0.121114521
32	–	2,399,584	218,416	–	–
33	25,000	1,391,280	1,068,144	0.117056877	0.029510137
34	280,000	2,079,440	2,079,440	0.020346771	0
35	–	2,491,588	642,532	–	–
36	–	7,434,372	1,851,300	–	–
37	548,900	14,674,264	14,674,264	0.073243693	0
38	–	4,934,556	2,789,292	–	–
39	–	4,532,880	4,532,880	–	–
40	300,000	7,266,820	3,829,012	0.034968146	0.029756055
41	–	5,583,820	3,259,036	–	–
42	–	6,084,232	3,535,048	–	–
43	–	7,723,100	2,508,044	–	–
44	324,000	6,687,120	-2,214,080	-0.018722138	0.075268053
45	104,000	6,348,276	6,348,276	0.167235933	0

(continued)

Table E.2 (Continued)

Case	Building Area	Water Use (gallons)	Q-cool-irr (Net indoor)	Qindoor/ sf/days	Qcool/ sf/days
46	–	5,692,280	3,394,424	–	–
47	–	1,922,360	513,128	–	–
48	–	8,563,104	727,056	–	–
49	–	3,111,680	526,592	–	–
50	–	224,400	224,400	–	–
51	–	16,830,000	3,590,400	–	–
52	81,000	5,048,252	1,122,000	0.037950279	0.114685743
53	110,000	4,099,040	260,304	0.006483288	0
54	33,000	2,778,820	855,712	0.071042922	0.141340639
55	140,000	139,470,584	135,171,080	2.645226614	0
56	139,000	9,273,704	3,362,260	0.066271016	0.057159673
57	–	41,271,648	-8,895,964	–	–
58	–	7,393,980	1,672,528	–	–
59	–	101,070,508	72,636,784	–	–
60	–	16,482,928	3,682,404	–	–
61	80,000	5,735,664	1,215,500	0.041626712	0.120550959
62	160,000	3,964,400	2,618,000	0.044828767	0
63	40,000	430,100	430,100	0.029458904	0
64	–	13,273,260	381,480	–	–
65	–	1,290,300	437,580	–	–
66	–	2,718,980	1,579,028	–	–
67	–	4,659,292	997,084	–	–
68	–	1,944,800	643,280	–	–
69	1,300,000	0	0	0	0
70	–	32,360,724	17,474,776	–	–
71	195,627	0	-3,148,332	-0.044091905	0.044091905
72	6,400	305,932	137,632	0.058917808	0
43	40,000	510,884	500,412	0.034274795	0
74	6,000	161,568	103,224	0.047134247	0
Mean	176,335	9,831,914.162	5,223,425.5	0.1168	0.0305
Std. Dev.	222,876.8	20,007,647.57	17,725,256	0.4181	0.0396
Min	6,000	0	-8,895,964	-0.0441	0
Max	1,300,000	139,470,584	135,171,080	2.6452	0.1413

Table E.3 Benchmarking measures for audit data Restaurants

Case	Total Building Area	Total Water Use (gallons)	Q-irr (indoor and cooling)	Qindoor/ sf/day	Qirr/ sf/day
1	–	1,742,840	1,668,040	–	0.102465753
2	–	6,058,800	5,997,464	–	–
3	8,000	1,534,896	1,534,896	0.525649315	–
4	4,000	1,223,728	1,205,028	0.825361644	0.051232877
5	4,000	2,853,620	2,820,708	1.931991781	0.060113242
6	4,000	2,744,412	2,658,392	1.820816438	0.102465753
7	4,000	1,635,876	1,635,876	1.120463014	–
8	4,000	1,056,924	1,056,924	0.723920548	0
9	4,000	4,772,988	4,772,988	3.269169863	–
10	5,120	1,849,056	1,849,056	0.989434932	0
11	5,000	2,280,652	2,242,504	1.228769315	0.052257534
12	3,000	357,544	357,544	0.326524201	–
13	37,000	822,800	822,800	0.060925583	–
14	10,000	2,496,076	2,383,876	0.653116712	0.038424658
15	5,000	3,650,240	3,605,360	1.975539726	0.122958904
16	6,000	3,137,112	2,912,712	1.330005479	0.122958904
17	4,500	2,992,000	2,842,400	1.730532725	0.136621005
18	4,500	1,398,760	1,398,760	0.851604262	–
19	2,200	1,720,400	1,653,080	2.058630137	0.083835616
20	60,000	1,454,112	1,454,112	0.066397808	0
21	5,600	5,132,028	5,117,068	2.503457926	0.017820131
22	10,000	1,484,032	1,484,032	0.40658411	–
23	14,000	2,541,704	2,389,112	0.467536595	0.052257534
24	25,000	5,035,536	4,783,460	0.524214795	0.086327397
25	3,000	3,457,256	3,457,256	3.157311416	–
26	5,000	7,685,700	7,685,700	4.211342466	–
27	20,000	3,654,728	2,668,116	0.365495342	0.122865753
28	–	3,081,012	3,081,012	–	–
29	12,000	2,692,052	2,692,052	0.614623744	–
30	3,000	1,484,032	1,326,952	1.211828311	0.071726027
31	–	2,822,952	2,033,064	–	–
32	20,000	2,042,788	1,389,036	0.190278904	0.099505632
33		7,772,468	7,772,468	–	–
34	10,000	3,815,548	3,647,248	0.999246027	0.076849315
35	10,000	4,773,736	4,773,736	1.307872877	–
36	18,000	2,298,604	2,022,592	0.307852664	0.10802818
37	14,000	1,782,484	1,764,532	0.345309589	0.024591781
38	11,,000	2,166,208	2,101,132	0.523320548	0.035658082
39	15,000	2,296,360	1,813,900	0.331305936	0.132180822
40	3,000	1,406,988	1,070,388	0.977523288	0.092219178
41	–	1,979,208	1,979,208	–	–
42	20,000	2,887,280	2,887,280	0.395517808	–
43	55,000	2,671,856	2,671,856	0.133093699	0
44	10,000	2,553,672	2,553,672	0.699636164	–
45	10,000	3,541,780	3,541,780	0.970350685	0

(continued)

Table E.3 (Continued)

Case	Total Building Area	Total Water Use (gallons)	Q-irr (indoor and cooling)	Qindoor/ sf/day	Qirr/ sf/day
46	10,000	3,599,376	3,599,376	0.986130411	0
47	10,000	1,878,228	1,878,228	0.514583014	0
48	30,000	2,645,676	2,645,676	0.241614247	0
49	8,000	2,255,968	2,255,968	0.772591781	0
50	7,000	3,077,272	3,077,272	1.204411742	0
51	11,000	1,715,164	1,715,164	0.427189041	0
52	5,000	3,273,248	3,273,248	1.793560548	0
53	9,400	2,137,784	2,137,784	0.623078986	0
54	6,000	1,965,744	1,965,744	0.8976	0
55	5,000	5,141,004	5,141,004	2.816988493	–
56	25,000	6,797,076	6,797,076	0.744885041	0
57	10,000	1,946,296	1,946,296	0.533231781	0
58	15,000	2,406,316	2,406,316	0.439509772	0
59	12,000	2,732,444	2,732,444	0.623845662	0
60	5,500	2,244,748	2,244,748	1.118180822	0
61	10,000	3,283,720	3,283,720	0.899649315	0
62	10,000	12,574,628	12,574,628	3.445103562	–
63	20,000	1,364,352	1,364,352	0.186897534	0
64	5,000	2,094,400	2,094,400	1.147616438	0
65	–	2,710,752	2,710,752	–	–
66	–	1,880,472	1,880,472	–	–
67	–	1,021,020	1,021,020	–	–
68	–	2,714,492	2,714,492	–	–
69	–	4,170,100	4,170,100	–	–
70	–	2,457,928	2,457,928	–	–
71	–	3,463,240	3,463,240	–	–
72	–	3,177,504	3,177,504	–	–
73	7,000	3,789,368	3,751,220	1.468187867	–
74	4,000	641,784	480,964	0.329427397	–
75	10,000	4,179,824	4,096,048	1.122204932	–
76	2,500	1,697,960	1,697,960	1.860778082	–
77	4,000	714,340	700,128	0.479539726	–
78	–	1,666,544	1,566,312	–	–
79	3,000	3,925,504	3,925,504	3.58493516	–
80	4,000	1,908,148	1,908,148	1.306950685	–
81	–	0	0	–	–
82	7,000	3,312,892	3,246,320	1.270575342	0.091194521
83	–	2,480,368	2,182,664	–	–
84	5,200	1,523,676	1,371,084	0.722383562	–
85	5,300	1,750,320	1,662,804	0.859552339	–
86	5,300	840,004	605,132	0.312810545	0.04766555
87	6,642	0	0	0	–
Mean	10,653.74	2,758,649.793	2,683,935.77	1.069522431	0.039239
Std. Dev.	10,588.45	1,825,244.078	1,838,021.642	0.908069273	0.047625778
Min	2,200	0	0	0	0
Max	60,000	12,574,628	12,574,628	4.211342466	0.136621005

Table E.4 Benchmarking measures for audit data Hotels and motels

Case	Total Building Area	Total Water Use (gallons)	Qcool/ sf/days	Q-cool-irr	Qindoor/ sf/days
1	55,000	8,927,380	0.000	8,916,160	0.444
2	80,000	23,838,012	0.127	19,877,352	0.681
3	45,000	206,448,000	0.000	206,376,192	12.565
4	60,000	0	0.000	0	0.000
5	60,000	8,239,220	0.000	5,684,800	0.260
6	50,000	1,769,768	0.000	1,769,768	0.097
7	55,000	3,343,560	0.000	3,083,256	0.154
8	261,000	3,044,360	0.008	2,180,420	0.023
9	417,000	29,810,792	0.029	25,173,192	0.165
10	65,000	7,287,016	0.000	5,538,192	0.233
11	68,411	0	0.000	0	0.000
12	65,000	7,506,180	0.000	5,930,144	0.250
13	45,000	7,569,760	0.000	6,812,784	0.415
14	200,000	5,935,380	0.000	3,680,130,.08	0.050
15	0	7,192,768	–	6,893,568	–
16	0	22,820,732	–	14,360,852	–
17	0	12,386,880	–	–	–
18	13,000	2,404,072	0.000	2,332,264	0.492
19	0	11,399,520	–	7,751,524	–
20	0	4,095,300	–	3,272,500	–
21	0	9,099,420	–	4,660,040	–
22	1,500,000	103,974,244	0.044	77,459,140	0.141
23	186,400	18,263,916	0.087	12,354,716	0.182
24	18,000	3,823,028	0.000	3,249,312	0.495
25	150,000	17,819,604	0.029	13,364,516	0.244
26	200,000	18,107,584	0.017	11,950,796	0.164
27	75,000	32,155,772	0.211	24,117,016	0.881
28	110,000	17,169,592	0.004	13,392,192	0.334
29	180,000	10,694,156	0.000	8,769,552	0.133
30	41,000	5,718,460	0.000	5,432,724	0.363
31	80,000	6,001,952	0.000	4,921,840	0.169
32	18,000	5,055,732	0.000	4,398,240	0.669
33	16,000	3,840,232	0.000	3,725,040	0.638
34	56,310	2,977,788	0.000	2,769,096	0.135
35	20,000	2,338,248	0.000	2,188,648	0.300
36	0	6,245,800	–	4,482,016	–
37	75,000	7,147,888	0.000	6,147,064	0.225
38	20,000	3,928,496	0.000	2,789,292	0.382
39	87,000	26,788,872	0.283	17,708,152	0.558
40	70,000	0	0.000	0	0.000
41	0	3,813,304	–	3,050,344	–
42	0	2,256,716	–	2,256,716	–
43	0	4,420,680	–	3,757,204	–
44	0	11,456,368	–	10,195,988	–

(continued)

Table E.4 (Continued)

Case	Total Building Area	Total Water Use (gallons)	Qcool/ sf/days	Q-cool-irr	Qindoor/ sf/days
45	0	11,222,992	–	11,222,992	–
46	660,000	17,480,760	0.007	13,984,608	0.058
47	–	10,543,808	–	9,911,000	–
48	–	15,593,556	–	14,969,724	–
49	–	3,400,408	–	3,128,136	–
50	–	7,539,840	–	4,372,808	–
51	–	8,212,292	–	8,047,732	–
52	65,000	4,211,240	0.000	4,042,940	0.170
53	–	8,581,056	–	8,581,056	–
54	–	2,728,704	–	2,455,684	–
55	–	7,028,208	–	4,989,908	–
56	–	6,636,256	–	–	–
57	–	6,331,820	–	6,205,408	–
58	–	5,481,344	–	5,262,180	–
59	44,000	4,832,080	0.000	3,865,664	0.241
60	350,000	23,006,984	0.043	17,485,248	0.137
61	0	26,686,396	–	23,217,172	–
62	–	12,716,000	–	10,172,800	–
63	–	1,983,696	–	1,886,456	–
64	0	52,193,196	–	49,270,012	–
65	–	0	–	0	–
66	–	0	–	0	–
67	0	0	–	0	–
68	0	4,507,448	–	4,236,672	–
69	–	8,711,208	–	8,711,208	–
70	–	13,487,188	–	12,407,824	–
71	27,000	3,163,292	0.000	3,163,292	0.321
72	–	7,997,616	–	7,357,328	–
73	110,000	3,014,440	0.000	2,781,064	0.069
74	–	3,748,976	–	3,336,828	–
75	440,000	23,379,488	0.015	19,170,492	0.119
76	–	0	–	0	–
77	170,000	17,788,936	0.020	15,654,144	0.252
78	300,000	24,523,928	0.022	18,883,260	0.172
79	–	19,275,960	–	-16,963,144	–
80	27,000	4,239,664	0.000	4,239,664	0.430
81	40,000	2,308,328	0.000	2,308,328	0.158
82	285,000	11,192,324	0.000	11,192,324	0.108
83	12,850	1,668,040	0.000	1,668,040	0.356
84	32,000	1,870,000	0.000	1,701,700	0.146
85	–	3,300,924	–	3,036,880	–
86	–	17,308,720	–	17,308,720	–
87	60,000	0	0.000	0	0.000
88	468,000	37,312,484	0.000	36,907,816	0.216
89	–	12,599,312	–	10,703,880	–
90	–	14,289,044	–	11,430,936	–

(continued)

Table E.4 (Continued)

Case	Total Building Area	Total Water Use (gallons)	Qcool/ sf/days	Q-cool-irr	Qindoor/ sf/days
91	–	5,721,452	–	5,663,856	–
92	–	307,932,152	–	218,646,384	–
93	–	0	–	-27,870,480	–
94	–	41,289,600	–	35,096,160	–
95	–	29,434,548	–	16,806,812	–
96	–	40,714,388	–	7,278,788	–
97	370,000	0	–	–	–
98	950,000	55,239,800	0.064	33,088,528	0.095
99	–	29,286,444	–	27,207,004	–
100	–	–	–	–	–
101	–	–	–	–	–
Mean	115,891.862	16,957,908	0.020	13,239,568.522	0.498
Std. Dev.	219,155.907	38,341,959.667	0.053	31,677,180.688	1.752
Min	0	0	0	-2,787,049	0
Max	1,500,000	307,932,152	0.283	218,646,384	12.565

Table E.5 Benchmarking measures for audit data for schools

Case	Total Building Area	Total Water Use (gallons)	Q-irr (indoor and cooling)	Qindoor/ sf/day	Qirr/ sf/day
1	384,000	4,305,488	4,305,488	0.03072	0
2	75,000	2,809,488	2,809,488	0.10263	0
3	174,240	2,276,912	2,276,912	0.03580	0
4	0	2,080,188	2,080,188	–	–
5	114,400	9,566,172	9,566,172	0.22910	0
6	22,000	5,613,740	5,613,740	0.69910	0
7	187,308	10,386,728	10,386,728	0.15193	0
8	96,400	1,352,384	1,352,384	0.03844	0
9	92,914	3,973,376	3,973,376	0.11716	0
10	0	8,856,320	8,856,320	–	–
11	500,000	24,325,708	7,121,708	0.03902	0.047134247
12	0	20,899,868	5,191,868	–	0.041165075
13	143,748	19,107,660	4,895,660	0.09331	0.039935371
14	130,680	24,009,304	4,561,304	0.09563	0.046332341
15	174,240	19,470,440	3,388,440	0.05328	0.043409137
16	130,000	16,898,816	3,651,736	0.07696	0.029748664
17	85,971	11,363,616	1,938,816	0.06179	0.045300649
18	74,519	8,334,216	1,303,016	47.90600	0.029187215
19	132,967	23,280,752	5,702,752	0.11750	0.048158904
20	80,000	9,709,040	1,406,240	0.04816	0.030938317
21	71,000	9,304,372	1,599,972	0.06174	0.037541921
22	234,000	18,710,472	8,687,272	0.10171	0.039683269
23	80,000	3,763,188	1,354,628	0.04639	0.065987945
24	76,500	5,046,756	706,860	0.02532	0.072766989
25	80,000	7,773,216	4,508,196	0.15439	0.041033304
26	87,000	7,824,828	943,228	0.02970	0.039347397
27	76,473	42,668,912	4,737,832	0.16974	0.233891426
28	160,000	20,228,912	4,247,892	0.07274	0.072972694
29	50,000	4,802,908	960,432	0.05263	0.074136137
30	–	6,408,864	3,204,432	–	0.030804441
31	210,000	5,085,652	966,416	0.01261	0.050158125
32	355,000	10,875,920	2,827,440	0.02182	0.036425648
33	53,000	4,235,924	804,848	0.04160	0.030719635
34	33,049	4,864,992	827,288	0.06858	0.036874009
35	81,760	10,457,788	2,300,848	0.07710	0.057302002
36	29,000	2,621,740	576,708	0.05448	0.036860707
37	37,000	2,200,616	857,956	0.06353	0.04180137
38	50,000	3,211,912	417,384	0.02287	0.043749949
39	80,000	9,325,316	2,207,348	0.07559	0.064788313
40	180,000	30,220,696	7,398,468	0.11261	0.079753383
41	155,000	14,152,160	3,758,700	0.06644	0.032692575

(continued)

Table E.5 (Continued)

Case	Total Building Area	Total Water Use (gallons)	Q-irr (indoor and cooling)	Qindoor/ sf/day	Qirr/ sf/day
42	71,000	16,942,948	1,525,172	0.05885	0.100333687
43	35,000	151,19,,324	1,058,420	0.08285	0.128410082
44	82,500	12,525,260	2,880,548	0.09566	0.037533904
45	35,000	8,385,828	1,760,792	0.13783	0.056194376
46	32,500	13,655,488	1,501,984	0.12662	0.106042265
47	35,000	11,125,752	2,002,396	0.15674	0.072661325
48	43,000	11,869,264	2,492,336	0.15880	0.091750763
49	64,900	16,242,072	1,461,592	0.06170	0.082641767
50	174,000	4,801,412	3,515,600	0.05536	0.060737459
51	80,000	6,742,472	1,955,272	0.06696	0.065578082
52	224,652	2,034,560	-10,307,440	-0.12570	0.044491709
53	–	22,748,924	6,394,652	–	0.10276657
54	34,000	5,538,940	1,495,252	0.12049	0.042609989
55	63,000	5,074,432	1,015,036	0.04414	0.033198904
56	128,000	9,117,372	1,619,420	0.03466	0.034237224
57	35,000	5,935,380	1,721,148	0.13473	0.052481096
58	40,000	5,773,812	1,212,508	0.08305	0.044631155
59	0	17,140,420	2,570,876	–	0.036287781
60	0	6,970,612	,976,140	–	0.041895946
61	0	9,287,168	1,671,780	–	0.031931553
62	653,438	61,818,460	25,072,212	0.10512	0.028887992
63	0	46,074,556	9,004,424	–	0.058288571
64	–	71,165,468	20,241,628	–	0.071175069
65	60,000	4,903,888	980,628	0.04478	0.03071045
66	160,000	7,655,780	918,544	0.01573	0.047087196
67	260,000	20,419,652	1,429,428	0.01506	0.044091535
68	209,593	30,403,208	15,505,292	0.20268	0.090702685
69	186,557	25,702,776	4,883,692	0.07172	0.060040617
70	57,147	12,536,480	1,127,984	0.05408	0.061893373
71	282,000	25,044,536	5,008,608	0.04866	0.074582817
72	384,000	44,983,224	9,446,492	0.06740	0.067424453
73	200,000	25,233,780	11,102,564	0.15209	0.054529099
74	150,000	20,000,024	3,600,124	0.06576	0.059120043
75	65,994	10,834,780	2,275,416	0.09446	0.046900625
76	200,000	25,007,884	3,250,808	0.04453	0.050687438
77	0	12,540,220	3,009,952	–	0.52220647
78	0	6,296,664	-4,309,976	–	0.337898694
79	0	6,807,548	1,973,972	–	0.027588904
80	–	5,532,208	1,604,460	–	0.071739689
81	0	2,632,960	2,132,548	–	0.062317808
82	0	6,771,644	5,305,564	–	0.060858447
83	0	2,315,060	1,825,120	–	0.061013699
84	0	3,076,524	2,425,764	–	0.040520548
85	0	4,723,620	2,767,600	–	0.081196347

(continued)

Table E.5 (Continued)

Case	Total Building Area	Total Water Use (gallons)	Q-irr (indoor and cooling)	Qindoor/ sf/day	Qirr/ sf/day
86	0	2,156,484	1,831,104	–	0.040520548
87	0	5,572,600	1,174,360	–	0.061479452
88	0	5,931,640	1,533,400	–	0.061479452
89	440,000	5,101,360	2,034,560	0.01267	0.071205015
90	0	4,387,768	3,564,968	–	0.032481939
91	0	4,338,400	1,540,880	–	0.04012795
92	–	4,532,880	1,974,720	–	0.071516914
93	0	11,519,200	11,519,200	–	0
94	0	2,591,820	1,215,500	–	0.037707397
95	0	2,069,716	1,022,516	–	0.047817352
96	0	2,013,616	1,684,496	–	0.051750381
97	152,460	2,805,000	1,376,320	0.02473	0.051347131
98	0	3,702,600	1,383,800	–	0.042194983
99	0	27,593,720	4,510,440	–	0.058073336
100	0	14,804,416	3,808,816	–	0.046133126
101	0	2,980,780	1,918,620	–	0.044563972
102	0	1,799,688	1,784,728	–	0.054648402
103	174,240	3,141,600	1,623,160	0.02552	0.047751487
104	0	51,391,340	32,890,308	–	0.053923148
105	0	2,398,088	804,848	–	0.041374797
106	0	3,493,160	3,081,760	–	0.051232877
107	0	4,142,424	3,192,464	–	0.047320548
108	0	5,132,028	2,960,584	–	0.045069406
109	0	9,256,500	2,359,940	–	0.053678082
110	0	4,859,008	1,384,548	–	0.054085616
111	0	16,353,524	8,514,484	–	0.081972603
112	0	6,821,760	2,086,920	–	0.051888658
113	0	3,900,820	893,860	–	0.047281029
114	0	2,468,400	1,226,720	–	0.050278791
115	0	4,237,420	1,305,260	–	0.060858447
116	0	4,455,088	580,448	–	0.040210046
117	0	4,645,828	1,816,892	–	0.014678995
118	0	2,990,504	1,980,704	–	0.04322774
119	0	2,280,652	1,517,692	–	0.039815264
120	0	3,459,500	1,724,140	–	0.054027397
121	0	1,861,772	1,046,452	–	0.050767123
122	0	6,059,548	3,157,308	–	0.041849171
123	0	14,574,032	7,512,912	–	0.039970112
124	0	14,929,332	6,327,332	–	0.061532959
125	131,384	–	–	–	0.027360491
126	–	8,003,600	1,496,000	–	–
127	34,540	11,758,560	1,175,856	0.09327	0.088126777
128	–	2,830,432	2,207,348	–	0.040970562
129	–	25,215,828	19,471,936	–	–

(continued)

Table E.5 (Continued)

Case	Total Building Area	Total Water Use (gallons)	Q-irr (indoor and cooling)	Qindoor/ sf/day	Qirr/ sf/day
130	–	33,007,744	11,222,992	–	–
131	–	10,344,092	7,044,664	–	–
132	–	7,106,748	794,376	–	–
133	90,800	52,707,820	39,389,680	1.18851	0.029416361
134	160,000	3,850,704	3,850,704	0.06594	–
135	150,000	2,280,652	2,280,652	0.04166	0
136	391,130	11,968,000	11,968,000	0.08383	–
Mean	83,788.47615	11,761,081	3,971,497.689	0.743770663	0.051164414
Std. Dev.	115,558.2931	12,328,836.3	5,750,738.271	5.559797098	0.03824609
Min	0	1,352,384	-10,307,440	-0.125703584	0
Max	653,438	71,165,468	39,389,680	47.90599511	0.37898694

APPENDIX F

CI CONSERVATION OPPORTUNITIES AND EXPERIENCE[16]

The foremost motivation for many water utilities to implement nonresidential conservation programs is that the sector represents a substantial share of total urban water demand. Also, because the distribution of water use in the CI sector is highly skewed (that is, a significant amount of water used by a relatively small number of customers), it is theorized that targeting high-end users can achieve significant savings per customer at relatively low administrative cost. This distinctive characteristic of the nonresidential sector makes nonresidential water conservation potentially cost-effective.

Early Conservation Efforts

In the 1990s, utility water conservation programs were increasingly focused on CI customers. Though industrial conservation programs such as recycling and wastewater reclamation programs had started earlier, in the late 1970s,[17] the process of planning, implementing, and evaluating conservation programs for the CI sector is just beginning for many water utilities. One of the earliest major audit programs was performed at the University of Texas at Austin campus where the project initiated a water recovery program in 1980 targeting "wasted water" from chillers for three dormitory drinking water sources (Osborne 1993). Expanded over the next decade, the water recovery program focused on re-plumbing other water-cooled research equipment, including lasers, electron microscopes, centrifuges, RF furnaces, condensers, compressors, and diffusion pumps. The value of the amount of water recovered, adjusted for changes in water rates during the 13 year period, was calculated as $2,530,000 for a total volume of 800 million gallons.

[16]This section discusses projects performed primarily in a few water-short states (especially in Arizona and California). Statistical findings and results may not be transferable to other locations, though many conservation impacts and lessons may be generalized.

[17]The California Department of Water Resources (1982) reported a significant increase in water re-use during the 1970s, especially in lumber mills, fruit processing plants, paper mills, and petroleum refining. Dziegielewski and Opitz (1987) estimated from statistics of Bureau of the Census (1981, 1986) that conservation contributed to a 40 percent decline between 1977 and 1982 in overall industrial water use from public supplies on a GED basis.

The City of Phoenix Water Services Department (PWSD) and the Massachusetts Water Resources Authority (MWRA) are two notable pioneers in CI conservation. For example, the PWSD began its nonresidential water conservation program in 1985 and the IBG (industry, business, and government) conservation program in 1992 (Ploeser, Kobrick, and Ciecior 1993). The MWRA constructed an industrial, CI water management program in 1986 to target the 500 largest water users through audits, workshops, and conservation documentation (Gorden 1996). Some of the more recent conservation programs are developed to target specific objectives. For example, in 1994, Seattle Water initiated two pilot programs, the Commercial Incentives Program and the Commercial Toilet Program to test program designs. In addition, Seattle (WA) also began a Commercial Conservation Potential Assessment (CPA) to learn more about what level of cost-effective conservation exists among commercial customers (Dethman and Associates, 1996).

Although a number of water utilities have made substantial efforts toward increasing water use efficiency in the nonresidential sector, documentation regarding these efforts is limited. A number of organizations, most notably the Phoenix Water Services Department, the California Department of Water Resources in co-operation with the Metropolitan Water District of Southern California, and the City of San Jose Environmental Services Department, have published some useful CI conservation guides targeted at different CI categories. The Phoenix Water Services Department has developed a state-by-state summary of conservation program efforts in the industrial/commercial/institutional water use sector.

CI Conservation Approaches

There are three fundamental approaches that water utilities around the country use to manage urban nonresidential water demand. The first is to encourage individual CI customers to improve *existing* water use efficiency. One way is to promote water conserving behavior by educating customers about the importance of water conservation. Customers are encouraged to operate water-using fixtures to the optimal and efficient level, and to minimize the level of waste, leakage, and unaccounted water, for example, through applying monitoring devices such as conductivity controls in cooling towers and a rainfall sensor for irrigation.[18]

[18]A study of water conserving plumbing fixtures in a junior high school in Tampa (FL) found that a reduction of 53% water use was achieved after the repair of leaks and replacement of faucets and toilets (Nero, Mulville-Friel, and Anderson 1996).

The second approach is to minimize water quantity per usage event by utilizing conservation technologies. A variety of domestic plumbing retrofit and rebate programs promoted by water utilities are aimed at replacing water-using fixtures with water-conserving fixtures, replacing high water-using practices with low ones such as Xeriscaping, ULFTs, and automatic shut-off fixtures.

The third approach is to maximize cycles per use by practicing internal recycling procedures, or using reclaimed water. Recently, water utilities also address the cost-effectiveness of building wastewater recycling plants and separate water piping or delivery systems for non-potable purposes such as irrigation and landscaping.

As shown in Table F-1, which lists examples of current or planned CI conservation projects in selected cities or service areas in the U.S. as of 1994-1995, the most common small scale conservation projects related to the CI sector are seminars, workshops, and conservation guides. The two popular financial incentives for participating CI establishments are conservation rate structures and plumbing fixture rebate programs. Many utilities have also begun detailed studies of the CI sector by conducting feasibility studies and surveys (e.g., Contra Costa, CA). Site-visits and CI water audits are also being conducted by most large water utilities in the west. Many major utilities have also implemented commercial toilet rebate and/or replacement programs such as those in Pasadena, San Diego, Petaluma/Rohert Park , and Santa Barbara (CA); Austin, and San Antonio (TX); Virginia Beach (VA), and in Seattle (WA) (See Table F.1).[19]

Advocacy Channels

To increase public awareness of CI water conservation programs, water utilities have sponsored workshops for commercial, institutional, and industrial customers to discuss methods to increase water use efficiency. These programs aim at increasing public knowledge of the needs and means of water conservation programs. Programs unique to the CI sector are employee awareness programs, audits, and site visits to CI sites, co-operative outreach programs, and low interest loan programs to compensate the sometimes large investment needed to convert to efficient technology. Audit programs of CI facilities can be larger in scale than audits of

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[19]For a detailed review of various CI retrofit programs in California, S. Dakota, and Washington, see Planning and Management Consultants, Ltd. (1994), annotations #2, #3, #8, #12, #23, #27, #33.

residential units because water uses are more complex, large, and diverse. Thus, conservation efforts and programs targeted at the CI sector may require commitment of substantial financial and staff resources.

Table F.1 Sample of current or planned CI projects in selected states

City/service area	Project description
Glendale, AZ	Pilot Program-liquid organic soil conditioner on turf areas of City park, ball fields and Mail Library grounds.
Goodyear, AZ	Water audits of high water use facilities.
Mesa, AZ	Water audit of small users with multiple facilities – convenience stores. Employee education program.
Paradise Valley Water Co., AZ	Large user audits.
Phoenix, AZ	Building and Facility Management, Cooling Tower Management, Implementation Program of the IBG (Industry Business Government) -- guidebooks, audits, hotels, schools, Annual mayor's award breakfast, BAT Conservation audits of large industrial/commercial facilities.
Tempe, AZ	Incentives, Some audits
Tucson, AZ	Business/industry/government conservation program, site visits of six user categories, cooling tower management education.
Azusa, CA	New construction Equals Water Savings – requires major water users to retrofit, large water users conservation plan.
Contra Costa, CA	Feasibility study on reclaimed water.
Corte Madera, CA	ULFT Rebate Program.
Fountain Valley, CA	CI water management program
Fremont, CA	Large landscape audit program, toilet rebate program
Glendale, CA	Business Assistance Survey, Reclamation Project
Los Angeles, CA	Financial assistance, CII program, Intern program for commercial water audits, Water management studies, Pilot projects, ULF rebate program, Water Conservation Advisory Committee, Water/Energy Conservation Partnership, landscape water management categories, Drought Busters, speakers bureau, typical water use audits – business.
Monterey, CA	Commercial Conservation Program
Oakland, CA	EBMUD/Chevron Water Reclamation Project
Pasadena, CA	Commercial retrofit program, commercial audit program, commercial water savings workshops.
Petaluma, CA	Direct-install CI ULFT replacement program
Rohnert, CA	Direct-install CI ULFT replacement program
San Jose, CA	Integrated water and energy conservation audits for large, CI facilities, technical assistance program to industry, financial assistance program, evergreen area landscape, audits, non-potable water reclamation
San Diego County, CA	CI water conservation programs
San Diego, CA	ULF toilet rebate program, city facilities retrofit program, large turf water management program, commercial /industrial survey program
San Francisco, CA	Commercial audits
Santa Barbara, CA	City facility retrofit program, retrofit programs to residential and non-residential

(continued)

Table F.1 (Continued)

City/service area	Project description
	customers
MWD, CA	Cooling tower water conservation seminars, CII conservation program assistance
Upland, CA	Water Saver fixture rebate program, water conserving landscapes, plant tagging program for local nurseries, table tent program
Ventura, CA	Government, utilities, and private industry partnership for water, wastewater, and energy efficiency, water audits of 36 large users
Denver, CO	Public agency water conservation
Washington, DC	Water Alliance for Voluntary Efficiency (EPA)
Miami, FL	Leak detection program, conservation rate structure, wastewater reuse
Honolulu, HI	Three non-potable water studies, 100 largest users program
Boston, MA	Meter downsizing program, automatic meter reading program, policy on sewer abatements, hydrant permits, ICI water audits, community relations.
Burlington, MA	Water and energy audits for Bolling and Hanscom, Air Force Bases, water use reduction design reviews for Fortune 500 companies.
Las Vegas, NV	Business cooperation program—Challenge 2000.
New York, NY	Pilot CI water audit program, planned toilet rebate program for all sectors, metering of cooling tower makeup water, study of cooling tower ozonation systems, competitive bid performance contracting for water savings.
Durham, NC	Plan future project evaluating methods to reduce commercial and industrial waste, survey on reclamation opportunities.
Albuquerque, NM	Large ICI water user audit program, cooling tower ordinance
Portland, OR	CII workshops, water audits, water reuse demonstration project.
Providence, RI	Implementation of a non-residential water audit program.
Austin, TX	ICI workshops and seminars, long-range projection for ICI benefits, municipal programs, commercial landscape irrigation audit training, commercial retrofit enforcement, CI water management.
San Antonio, TX	Rebate programs for ULFTs, business and home water conservation audits, extensive reuse plan, conservation rates plan, comprehensive CI conservation program
Virginia Beach, VA	Water conservation awareness committee, ICI toilet rebate program, Water Wise demonstration garden
Seattle, WA	ICI conservation workshops, financial incentives for business (cover up to 50% of retrofitting), commercial customer surveys, commercial price response study, commercial toilet, showerhead urinal retrofit programs, commercial irrigation audits, cooling tower user water audits
Vancouver, WA	Water audits of city facilities

Source: Compiled from Incon.net (1994-1995).[20]

CI Audit Programs

Many utilities have designed and implemented audit programs to address water conservation opportunities for commercial, industrial, and institutional water use. These programs often target specific large water users identified by utilities from water billing records.

[20] A hard copy was provided by Jane Ploeser of City of Phoenix Water Services Department.

A series of pilot water audits is often performed to identify and quantify the patterns of water usage in the CI sectors.

An increasing number of case studies are showing significant reductions in water use from CI audits, and have developed methodologies to demonstrate the potential savings that are available. For example, Denver Water initiated the commercial and industrial water audit program in 1990. Under the program, 36 of the top 100 commercial and industrial water users were selected for water audits. These establishments included such commercial categories as hotels, restaurants, health care, office space, schools, and line/laundry suppliers. Water use reductions attributable to implemented conservation measures ranged from 3 percent to 29 percent for the five case study facilities (Black & Veatch 1991, Bjorgum and Hernandez 1993).

CI Plumbing Retrofit Programs

In the past decade, ultra-low-flush (ULF) toilet replacement programs have been popular. These programs target the older, less efficient 3.5 and 5.5 gallon per flush toilets and replace them with 1.6 gallon per flush toilets.[21] Although most programs have targeted residential water users, some programs have targeted commercial and institutional facilities.

The first major CI ULFT retrofit program started in Santa Barbara County in 1987. Faced with long-term water supply deficiencies, the Goleta Water District took the lead on changing the California Plumbing Code, which was changed in 1994 to require ULFTs at 1.6 gpf (Hagler Bailly Services, 1997a).[22] The program provided commercial and residential customers with cash rebates. The customers were also provided with free 2.5 gpm showerheads and faucet aerators. The program aimed at retrofitting 50 percent of commercial and residential toilets (over 20,000 fixtures) within five years.

The San Diego Water Utilities Department initiated a ULF toilet retrofit program in 1992 for 350 public buildings containing over 1,800 toilets. Four major categories of public facilities were targeted including police stations, fire stations, libraries, and others. Results were evaluated based on 70 sites and showed that water savings varied across categories within the public sector. The number of users, number of toilets per facility and the nature of the facility

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[21]In the CI sector, flushometer-type toilets predominate for most heavy traffic establishments. The hotel/motel sector and small sites generally use tank-type toilets because they are relatively cheap to install compared to the flushometer-type toilets.

[22]However, the CI ULFT program started only in Phase II of the program in 1992.

were some of the factors affecting water savings in these public facilities. The least savings occurred in police stations (20.5 gallons per toilet per day (gtd)), and the most savings occurred in recreation centers, senior centers, and pools with an average of 116.8 gtd (Bamezai and Chesnutt, 1994).

A major ULFT study looking at CI toilet retrofits was conducted for the California Urban Water Conservation Council between 1992 and 1996 (Hagler Bailly Services, 1997a). The project evaluated the effect of ULFTs in 12 market segments of 10 California water agencies. The study estimated the following savings per installed ULFT:

- 36 gpd for automotive
- 48 gpd for food stores
- 21 gpd for health care
- 16 gpd for hotel/motel
- 20 gpd for offices
- 28 gpd for religious facilities
- 47 gpd for restaurants
- 37 gpd for retail
- 57 gpd for wholesale
- 29 gpd for multiple use sites
- 23 gpd for manufacturing
- 17 gpd for miscellaneous CI sites
- Savings for schools could not be estimated with statistical accuracy

Using the Hagler Bailly unit figures, Nelson (1998, 1997a, and 1997b) calculated weighted average savings in a widespread CI ULFT replacement project conducted in Petaluma and Rohnert Park (CA) to be 26 gpd per typical CI toilet installation. End use monitoring of a representative sample of participating CI categories came up with the same unit value. The program involved replacement of 1,090 CI toilets in 213 CI sites. Eighty-two percent of the replacements were flushometer or pressure assisted flush toilets. A comprehensive follow-up customer satisfaction survey sponsored by AWWA was conducted on both programs and demonstrated high satisfaction (Nelson and Weber, 1998). Double flushing in new ULF toilets was found to be less for all types installed except for new flushometer toilets. The distribution of new toilets installed was: pressure assisted gravity flush (60 percent), flushometers (21 percent), gravity flush (18 percent), and vacuum assisted gravity flush (1 percent).

Another study evaluated ULFTs at an airport in Denver, Colorado and found water savings to be 1.05 gallons per patron for men and 1.99 gallons per patron for women (Stevens Institute of Technology, 1992).

In Tampa, Florida, a junior high school was targeted for the institutional and multi-family low-flow retrofit program in 1993. Existing facilities were repaired before retrofitting the low-efficiency facilities. It was found that the school obtained savings of 29 percent with the repair of existing facilities. Installation of ULF fixtures resulted in another 32 percent savings. However, 10 percent of participating customers felt the ULF faucets and 4 percent felt the ULF toilets were worse than the previous fixtures.

The studies described above are only a small portion of the CI ULFT conservation programs that have been implemented. There are far too many to mention in this report.

Other Indoor Conservation Programs

There are a few studies that targeted specific CI sites or categories. For example, in 1989, the Jewel Cave National Monument in Custer, South Dakota undertook a water use reduction program to limit the volume of wastewater accumulating in its lagoon. The program retrofitted the monument quarters and visitor center with ULF toilets and low-flow showerheads. The retrofit program resulted in a 52 percent decrease of water use from the previous season (Dilts, 1993). This conservation program not only achieved savings of potable water, but also reduced the volume of wastewater.

The El Dorado Hospital and Medical Center Water Conservation Program of 1993 in Tucson (AZ) is another example of a conservation program implemented at a specific site. The program consisted of six measures to reduce water use and reduce hazardous pollutants. Converting cooling tower make-up to hard water reduced the use of water softening chemicals. The water softening system received more efficient controllers to minimize salt and resin use. X-ray processor water was recycled and some processors were shut down during low use periods. The laundry system was updated with more efficient washers requiring 50 percent less water per pound of linen washed. All faucets had flow restrictors installed and low-flow showerheads were retrofitted in all patient showers. The irrigation system was repaired and updated to more efficiently water the ground. Though no data were presented to indicate the total volume of water saved, the payback period for return on investment period for all measures was estimated at between one and three years (El Dorado Hospital, 1993).

In another study, office buildings were used to study the effect of the 1989 amendment to the New York State Plumbing Fixture Law of 1980 (Behling and Bartilucci, 1992). Based on a study of ULF plumbing fixtures in office buildings in New York state, it was found that installation of modern ULF fixtures has the potential to significantly reduce water consumption in office buildings in the range of 59 to 69 percent of water usage compared to pre-1980 fixtures. The savings were in the range of 44 to 45 percent of water usage if compared to 1980 standards.

Another study of a plumbing retrofit program in office buildings was the Bellevue City Building Plumbing Retrofit Program of 1992 in Bellevue (WA). The city of Bellevue replaced 83 toilets and 28 urinal flush valves in three municipal buildings. The total cost of the program was about $35,000 which was projected to result in savings of $63,600 over the project life of 25 years.[23]

In the literature, there are two documented conservation efforts at zoos. One is the audit program at the Zoological Society of Philadelphia started in 1991. It was estimated that continuous water use throughout the day and overnight for irrigation, exhibition, and water features accounted for about 91 percent of total usage. Daytime uses of Zoo staff and visitors, water used for animal care, and water used for other cleanup and maintenance only accounted for about eight percent of total demand. Overnight uses such as cleaning and maintenance accounted for about one percent. Many changes were recommended including repairs of leaks, installing of pressure reducing valves, and recycling. In addition, operational changes were recommended such as changes in cleaning procedures. Implementation of all recommended improvements, both capital and operational, were expected to result in a reduction in daily water usage of about 48 percent. The major portion of the expected water savings resulted from eliminating leaks throughout the Zoo (Richards, et. al., 1993).

The other zoo conservation project was at the San Francisco Zoo. It was recommended that the zoo irrigate using recycled water from the City's Recycled Water Program. Limitation

[23]Nevertheless, the savings were believed to be underestimated because the Municipal Building experienced erratic water consumption during the post-retrofit monitoring period as a result of possible leaks (City of Bellevue Public Works Department, 1993).

of the use of high quality potable water for only required purposes was also recommended. Alternative supplies of non-potable water were to come from groundwater and reclaimed water where possible and appropriate. This conservation proposal utilized various grades of water sources and demonstrates the uniqueness of integrated resources planning (Teien and Kubick, 1996).

CI Landscape Conservation Programs

Landscape programs in the CI sector are usually designed to target large landscape water users such as golf courses, parks, and recreational·facilities. The objective of large landscape programs in general is to maximize water use efficiency for landscape maintenance. Efficiency can generally be enhanced by fine tuning the irrigation system, adjusting watering schedule, and/or by replacing watered landscape with low-water using plantings. The concept of Xeriscape is often used to describe conservation procedures in landscape programs. Xeriscape is an approach to landscaping that alters the landscaping so that its water requirements are met largely by natural precipitation. Florida was the first state in the country to institute a statewide Xeriscape law. This law required every local government to consider enacting Xeriscape regulations (if it determines that the benefits outweigh the costs) by October 1, 1992 (Adams, Brockway, Kavouras, 1996). The California Department of Water Resources adopted the Model Water Efficient Landscape Ordinance in 1992. Texas also initiated the Commercial Landscape Ordinance in 1993.

Water application can be reduced by adopting water efficient irrigation equipment, and installing technologies such as pressure regulation valves, pressure compensating spray nozzles, and drip irrigation. There has also been some installation of soil moisture sensors and rain sensors that shut-off automatic sprinkling systems during periods of sufficient soil moisture and or rainfall.

Irrigation management practices can be changed to reducing irrigation time and unify the application rate[24] of water with advanced equipment. Changing irrigation schedules was found to have the greatest potential for conservation with the lowest associated cost in the CI pilot program in Tampa, Florida (Nero and Davis, 1993).

[24] A uniform distribution of water the sprinklers apply improves efficiency.

The implementation of landscape-oriented CI conservation programs involves many resources and partnerships. The conservation process needs cooperative and coordinating efforts from property owners and developers, the landscape industry (architectural and design firms, nurseries, and most importantly maintenance companies), manufacturers of irrigation fixtures and chemicals, and the water industry. The "cash-for-grass" style of program which offer rebates for Xeriscaping and for sprinkler head upgrades, is one of the few economic incentives used to promote landscape conservation programs. Other programs have included workshops and public education. Las Vegas (NV) has offered several Cooperative Extension programs such as Coffee With Friends seminars, Nursery Certification seminars, and the Fundamentals of Horticulture classes. Florida has a statewide Xeriscape training program for the retail home improvement industry, which includes a video tape, plant guides, and specific Xeriscape instructions (Adams, Brockway, and Kavouras, 1996).

The North Marin Water District and the Marin Municipal Water District initiated a coordinated Irrigation Management Program in 1986. After two years, the program had conducted 66 audits of the largest irrigation customers on a total of 427 acres, and consisted of training workshops for turf irrigation managers. The training program was shown to reduce peak month demand of the trained customers by 7.3 percent, resulting in a benefit-cost ratio greater than one. The field audits were found to reduce water use from 10 to 20 percent and have an estimated benefit-cost ratio of 4.9 (Nelson, 1989).

North Marin Water District selected 21 commercial/government customers with annual water consumption of 400 cubic feet or greater for an audit program in 1989. These sites were asked to reschedule their irrigation time according to the local evapotranspiration rate (ET)[25] provided by the California Irrigation Management Information System (CIMIS) network. Essentially, these real time ET data were utilized to determine the optimal watering schedule for each audit site. Regression analysis revealed that significant water and energy savings resulted from improved scheduling and application of irrigation water to the sites. Government turf areas

[25]ET is an indication of how much water evaporates from the soil and transpires from the plants and thus is also an indicator of irrigation requirement. A detailed description of the Landscape Coefficient Method for Estimating Water Requirements of Landscape Plantings developed by the University of California is in Bock (1993).

participating in this program showed a 16 percent reduction in water use, while an ET based irrigation schedule for a private park revealed savings of 7.7 percent (Bourg and Nelson 1993).[26]

In a similar program, the City of Tampa initiated an audit project in 1992 that targeted 14 commercial/business properties, 8 multifamily complexes, and 3 education facilities. The program was aimed at determining irrigation efficiency and providing a cash-match to encourage implementation of suggested changes in CI and multi-family properties. The properties were evaluated against three factors: distribution of unity (which is a measure of how evenly water is applied by the sprinklers); potential efficiency (which is an indicator of applied water that is beneficial to turf growth compared to total water applied); and a deficit fraction (which is an index of under-irrigation). Recommended changes included scheduling adjustment, reduction in irrigation time for individual zones, elimination of some irrigation days, and incorporation of seasonal irrigation cycles. These changes were estimated potentially to save 28 percent of total water used.

In 1983-1984, the City of Austin (TX) initiated a water conservation program that included Xeriscape as the major outdoor measure. To accomplish this task, the Xeriscape Program included a multi-level marketing approach. Public information programs such as a Xeriscape newsletter, brochure, and a video were offered. Other Xeriscape events such as the Annual Texas Xeriscape Conferences, Xeriscape schools in Austin Community Adult Education Class, Austin Area Garden and others were also organized. In 1992, a pilot program was implemented to audit residential irrigation water use. In 1993, the program was expanded to include commercial irrigation audits.[27]

CI CONSERVATION COSTS AND BENEFITS

In order to attract and motivate participants into programs, such as those just described, the costs and benefits of these conservation programs must be evaluated. This section reviews two issues relating to CI conservation costs and benefits. First, alternative perspectives are examined on who pays the conservation costs. Next, a review is performed of direct costs of CI

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[26]The causes for the significant program savings could not be directly proven since water use at the scheduled sites did not correlate well with ET in the regression study.

[27]A rebate program "Xeriscape It!" initiated in 1993 was offered to residential water customers, but not CI customers.

conservation, followed by a review of achieved water savings and return on the conservation investment.

Accounting Perspective

The costs and barriers of CI conservation efforts can be evaluated from five different perspectives: (1) program participant perspective (2) ratepayer perspective (3) total resource cost perspective (4) utility cost perspective, and (5) societal perspective (Dziegielewski et al. 1995).

The participant perspective considers that conservation practices often involve costs for replacing equipment with conservation technologies that are considerably more complex and potentially disruptive to current business practices or operational procedures. The impacts of conservation practices on profitability and quality of services are uncertain. In addition, water cost is relatively small compared to other input costs, such that it is less likely a priority in budgeting. Furthermore, the majority of water users in CI establishments (such as employees and customers) are not directly responsible for paying water costs, so that price responsiveness is inelastic in the sector. Auditing may involve a loss of confidentiality for many CI establishments, which may make it difficult for the potential participant to cooperate with the auditor or the water utility.

The ratepayer impact perspective measures the effects that changes in water utility revenues and operating costs have on customer water rates. This perspective examines the direction and magnitude of the expected change in customer water rates and bills and reflects the shifts in the burden of costs. In many demand reduction programs, the revenues that the utility loses must be recaptured through rate increases.

The utility cost perspective measures the net costs of a water conservation program as incurred by the utility. Water conservation measures that result in measurable reductions in water use should also result in both reduced operating costs and reduced revenues. With reference to conservation programs targeting the CI sector, the share of CI use of total urban water demand is relatively small when compared with residential use for most jurisdictions. In addition, the number of large CI entities in small jurisdictions is limited, so savings are both limited and site specific. The cost of achieving CI water savings can be significant, especially for small water utilities.

The total resource cost (or *community*) perspective combines the economic effects of a program on both the customers participating and those not participating in a program. It measures the net costs of a program as a resource option based on the total costs of the program.[28]

Finally, the *societal* perspective goes beyond the total resource perspective in that it attempts to quantify the total resource costs as a whole rather than to only the costs to the water service area. It also includes the effects of externalities such as environmental impacts and other external costs and benefits.

Itemized Direct Costs of CI Conservation

Survey Costs

To evaluate the potential for conservation, water utilities often commission external consultants to perform surveys. These efforts incur survey costs to the utilities and in the meantime typically generate conservation guidebooks, databases, baseline studies, and other materials that describe that state of knowledge of water use patterns and forecasts of future developments. These costs can be measured in various units as shown in Table F.2 which reports average survey direct costs per site, direct survey cost per CCF saved, and direct survey cost per acre-foot (AF) saved by each CI category.

Hagler Bailly Services (1997b) estimated that CII surveys are more cost-effective at larger water-using sites. By comparing the direct survey cost per CCF saved in different CI categories, the lowest survey costs were related to recreation and utilities categories. The direct cost of surveying these sites per AF of water saved was projected to be $50 or less. These CI categories constitute 48 percent of the total lifetime water savings reported as implemented via the survey. The highest survey costs were incurred, in descending order, at religious organizations, nursing home and personal care, laundry cleaning, and government categories. The direct survey cost per AF saved ranges from $710 to $195.

[28]Community leaders and citizens alike do not want the economy of the area to be negatively impacted by restrictions on use and leaders are much more willing to forgo lawn watering than water for businesses. This is particularly true and well demonstrated during periods of drought. Even during times of plenty, political leaders rarely want to entertain any negative impacts on business and in fact often offer new business discounts and favorable treatment to induce them to come to their city and bring new jobs with them. Conservation for CI then must be approached as a cost-effective efficiency measure to assure business enjoys a win-win situation.

Table F.2 Survey costs by CI category

CI categories	Site count	Average survey direct cost per site ($)	Direct survey cost per CCF saved (projected) ($)	Direct survey cost per AF saved (projected) ($)
Recreation	18	1,568	0.04	18
Other	10	493	0.08	33
Utilities	7	1,357	0.08	36
Education	112	720	0.11	46
Hotels, motels, & tourist courts	58	816	0.12	50
Car wash	9	1,356	0.17	73
Offices	37	778	0.18	79
Eating & drinking places	65	503	0.22	96
Trucking terminal facilities	18	567	0.22	98
Hospitals	10	3,263	0.23	101
Industrial	124	2,373	0.24	103
Retail/wholesale	62	598	0.25	108
Government	11	841	0.45	195
Laundry, cleaning, & garment	5	2,135	0.64	277
Nursing & personal care	51	1,097	0.78	338
Religious org.	8	488	1.63	710
Total	605	1,154	0.17	74

Source: Adapted from Hagler Bailly Services (1997 b). Table 5-6.

Conservation Technology Investment

The adoption of conservation technologies does not necessarily require customers to change their water using habits. However, the investment can be costly, especially when the selected conservation technologies are more sophisticated. Within the CI sector, the cost of conservation investment varies by the size, diversity, and intensity of technology utilization at each site as shown in Table F.3 for a case study in Florida. The average cost of changes due to conservation was most expensive in the hospital category. This is perhaps due to the size of a typical hospital and the diversity and intensity of technology involved in a hospital. The savings of Table F.3 show an average payback period of 1.4 years in hospitals.

According to the data of Table F.3, the cost of technological changes was the lowest in the restaurant category. The payback period is less than 6 months, making the category possibly the most cost-effective target for CI conservation. Investments in conservation technologies in office buildings are shown to have the longest estimated payback period within these five selected categories, even though the cost of changes is moderate.

Table F.3 Potential savings and costs of CI conservation

	Potential annual savings			**Cost of changes**	**Payback**	**Cost of survey**
Category	**(gallons)**	**($)**	**(%)**	**($)**	**(years)**	**($)**
Restaurants	621,279	3,507	29	1,532	0.4	1,148
Hotels/Motels	1,911,705	7,940	24	10,583	1.3	978
Office Buildings	1,010,549	4,893	19	8,195	2.0	1,080
Schools	1,803167	6,531	22	6,735	1.5	3,095
Hospitals	17,340,605	63,118	51	85,500	1.4	4,557

Source: Derived from Southwest Florida Water Management District (1997). *ICI Water Conservation in the Tri-County Area of the Southwest Florida Water Management District.* Brooksville, FL. Table 2.

CI Conservation Benefits

CI conservation programs can benefit water utilities in the same ways that residential programs do, but CI programs create their own unique benefits. Water utilities may achieve greater savings with fewer customers. The highly skewed concentration curve of water consumption in the CI sector makes for greater potential savings per customer and lower administrative costs for operating programs. Water utilities may also integrate water conservation programs into other programs to reduce implementation costs, such as energy conservation or pre-treatment and waste minimization programs. CI conservation programs also allow water utilities and large users to show the community that they support water conservation and the environment.

With regard to individual CI establishments, cost-effective conservation strategies result in a reduction of water quantities and associated savings in water charges. Larger water users may especially be motivated to conserve water because of potential water cost savings and other positive externalities such as reduced sewer, wastewater, and energy costs. The amount of water and cost savings depends on the extent of conservation technologies implemented and the extent of employee conservation awareness and efforts.

The economic analysis of conservation benefits is centered on the customer payback period, which is the time period needed to accrue enough water cost savings (direct savings plus indirect savings) to compensate for the total costs of investment in conservation equipment. For example, Seattle Water has calculated from their 26 completed water conservation projects during 1994-1995 that the median project payback was 2.9 years (in absence of any financial incentives). The Massachusetts Water Resources Authority (1986) audited 40 sites and estimated that conservation actions resulted in payback periods of 5 months to 3 years.

Identified Potential Savings by CI Category

Potential savings have been identified in many audits. However, due to different methods of auditing, different choices of CI establishments, and other site-specific characterizations, it is difficult to obtain a generalized water savings figure for each CI category. In many cases, it is easier to show savings for a specific site.

A major CI conservation program conducted over 903 CII sites by the Metropolitan Water District of Southern California between 1991-1996 reported average potential percentage water savings per year for 10 selected commercial categories and five institutional categories, and offered a look at possible quantifiable savings (ERI Services 1997). The average potential water savings per year for the commercial sector is about 20 percent of average consumption, and that of the institutional sector is about 19 percent.

Another study conducted by the U.S. Environmental Protection Agency (EPA, 1997) found that commercial water-use volume may be cost-effectively reduced by approximately 22 percent. The largest volumes of potential savings are in the categories of health care, offices, hotels and accommodations, sales, eating and drinking, education, laundries, landscape irrigation, and recreation. The study offers a range of water savings with and without irrigation, as shown in Table F.4.

Table F.4 Range of audited minimum and maximum savings with and without irrigation

CI category*	Count site audits	Without irrigation Min savings (%)	Without irrigation Max savings (%)	With irrigation Min savings (%)	With irrigation Max savings (%)
Car wash	12	2.52	69.52	4.34	69.52
Church-nonprofit	19	0.00	47.67	0.00	61.20
Communication & research	10	1.91	74.22	1.91	74.22
Corrections	2	8.48	9.95	9.95	18.61
Eating & drinking	102	0.00	85.32	0.00	85.32
Education	168	0.00	78.97	0.00	78.97
Healthcare	90	0.00	64.31	0.71	65.42
Hospitality	222	0.00	85.32	0.00	85.32
Hotel	120	0.00	53.21	0.00	53.21
Landscape irrigation	6	0.00	42.93	2.48	42.93
Laundries	22	0.00	61.83	0.00	61.83
Meeting/recreation	20	1.19	55.64	1.19	75.79
Military	1	8.84	8.84	8.84	8.84
Offices	19	0.00	51.38	0.00	60.87
Sales	56	0.00	72.72	2.10	72.72
Services	58	0.00	74.19	0.00	74.19
Transportation & fuels	24	0.00	65.04	0.00	84.29
Utility & construction	3	11.73	802.36	11.73	804.62
Vehicle dealers & services	12	0.30	26.16	2.24	32.48
Total	744				

* The MWD database of commercial water audits was used for quantifying potential water savings percentages. The City of Tucson, Arizona and the Massachusetts Water Resources Authority (through its consultant—ERI Services) also provided additional site date. The initial data included 194 site audits that were later expanded to 744 audits.
Source: Adapted from U.S. Environmental Protection Agency (1997). *Study of Potential Water Efficiency Improvement in Commercial Businesses: Final Report.* Sacramento, CA: The Resources Agency, Department of Water Resources, State of California. Appendix 2.

Identified Potential Savings by CI Measure

Table F.5 provides information on the potential savings that may be derived from specific CI conservation technologies. These data suggest that, excluding potential savings from industrial sites and waste treatment plants, the biggest percentage share of total potential savings is from sanitary measures, which account for 17 percent of total potential. Within the category of sanitary measures, installing ULF toilets seems to have the greatest impact on water savings in terms of amount of potential water saved. Reducing irrigation schedule time is also indicated as holding relatively large savings potential.

Table F.5 Summary of potential savings per site by measure category

Measure category	No. of times measure was recom-mended	No. of units recom-mended	Potential savings (ccf/yr)	% of total potential (by category)	Total potential Savings per site (%/yr)
Sanitary					
Install faucet aerator	530	28,170	106,410	0.9	1.4
Install flow straightner	69	5,967	43,624	0.4	3.1
Install toilet retrofit kit	103	3,384	37,372	0.3	2.0
Install ULF showerhead	119	8,075	70,600	0.6	3.8
ULF toilets	616	20,102	576,850	4.7	7.0
Urinal retrofit kit	514	5,555	135,326	1.1	1.7
Other sanitary measures	106	2,240	47,448	0.4	
Sanitary Subtotal	2,057		1,017,630	8.4	
Cooling					
Adjust blowdown cycles	188	363	176,220	3.9	4.3
Install controls	31	49	52,430	1.1	17.0
Other cooling measures	11	12	12,412	0.3	
Cooling subtotal	230		241,050	5.3	
Cooling (Waste Treatment Plants)					
Eliminate once-through	3		1,912,400	80.5	
Irrigation					
Install controls	12	20	16,595	0.2	4.7
Reduce schedule time	395	395	529,930	8.0	8.4
Other irrigation measures	12	18	16,785	0.3	
Irrigation subtotal	419		563,310	8.5	
Laundry					
Front loading machine	10	269	13,521	1.0	10.2
Load to capacity	84	84	18,145	1.3	1.7
Other laundry measures	9	9	29,344	2.2	
Laundry subtotal	103		61,010	4.5	
Kitchen					
Auto shut-off nozzle	35	51	5,200	0.1	1.5
Faucet aerators	57	166	4,300	0.1	0.8
Flow straightness	142	812	33,170	0.9	1.4
Reduce dishwasher loads	38	42	2,170	0.1	0.5
Auto. shut-off nozzle	66	75	4,795	0.1	0.8
Replace faucet	9	15	1,070	0.0	2.3
Scrape dishes	27	21	2,480	0.1	0.8
Other kitchen measures	28	33	6,785	0.2	
Kitchen Subtotal	402		59,970	1.6	
Process measures	316		2,243,990	23.2	37
Grand Total	3,500		6,100,000	29	

Source: Adapted/derived from ERI Services (1997). "Commercial, Industrial, and Institutional Water Conservation Program: 1991-1998." Table 8 and Table 9.

Since not every technical measure is suitable for individual CI categories, Table F.6 estimates the water saving impacts of various measures across different CI categories. Installing ULF toilets dominates identified water savings in all CI categories except in car washes, laundry and garment cleaning, and utility facilities. In these three CI categories, recycling process water generates far more water savings than installing ULFTs. Installing new front loading machines could save substantial amounts of water over the lifetime of the equipment in laundry, garment cleaning, and nursing and personal care facilities.

It is difficult to judge whether conservation measures and water savings such as those listed in Table F.6 and Table F.7 are cost effective, since cost effectiveness depends on the number of measures implemented and total costs of these implemented measures. Total costs need to be compared with the total value of water savings (unit prices * ccf. per lifetime) in order to judge whether the value of savings is indeed greater than the cost of implementation.

Implementation Rate

An alternative way of evaluating the success of CI conservation programs is to compare the implementation rates of individual conservation measures. An implementation rate, in its simplest definition, is the percentage share of total identified water savings measures that have been implemented.

Table F.8 reports estimated implementation rates associated with recommended CI conservation measures by customer group for nonresidential establishments in Southern California.

The data could be interpreted such that the implementation rate for each CI category represents the willingness and the effectiveness of conservation programs targeted within these categories. The data show that the hotel/motel category implemented the most measures recommended, followed by retail or wholesale establishments. Nursing facilities offered the smallest implementation rate and generated the smallest portion of potential savings realized among the reported categories.

While looking at corresponding implementation rates of individual conservation measures (see Table F.9), irrigation conservation measures, such as reduced irrigation scheduling time, seem to offer a lot of potential for conservation targeting. Also, changing cooling operational practices, repairing leaks in kitchen appliances, replacing faucets, and installing ULF fixtures have high implementation rates.

For those measures and categories for which implementation rates are low, the single most important factor influencing the implementation of recommended conservation measures is the payback period (Hagler Bailly Services, 1997b). Put simply, customers who can quickly recover their direct costs for adopting measures are more likely to adopt the measures. As shown in Table F.10, scheduling problems and general lack of interest can also represent important barriers to CI conservation efforts.

Table F.6 Identified water savings by CI category and measure (% of total annual use)

Specific measure	Car wash	Eating & drinking	Hospitals	Hotels	Laundry	Nursing	Offices	Recreation	Retail
Adjust blowdown cycle	0.000	0.042	3.961	2.426	0.000	0.227	5.436	1.877	4.954
Adjust equipment	0.000	0.401	0.407	0.289	0.412	0.471	0.115	0.726	0.007
Change operational practices	0.869	1.234	2.728	0.034	0.000	0.000	1.018	5.329	4.314
Install automatic shut-off nozzle	0.000	0.225	0.000	0.134	0.000	0.154	0.000	0.021	0.176
Install faucet aerator	0.087	2.077	1.726	4.985	0.131	1.514	1.019	1.564	1.586
Install flow straightner	0.000	0.766	4.655	1.767	0.024	4.059	0.589	0.070	0.788
Install misc. equip. & parts	1.749	0.631	2.697	0.062	0.879	0.573	0.067	0.713	0.107
Install new front loading machine	0.000	0.000	0.000	0.000	7.372	0.861	0.000	0.028	0.000
Install spray nozzle	0.000	0.000	0.002	0.000	0.000	0.011	0.000	0.000	0.000
Install toilet displacement device	0.000	0.038	0.000	0.073	0.000	0.000	0.017	0.000	0.003
Install toilet retrofit kit	0.000	0.920	0.078	0.355	0.000	0.247	0.266	0.408	1.312
Install ULF showerhead	0.000	0.005	0.238	5.252	0.000	0.692	0.634	0.196	0.339
Install ULF toilet	0.914	14.073	13.752	8.145	0.361	14.207	9.637	10.051	6.703
Install ULF urinals	0.000	0.069	0.000	0.049	0.000	0.201	0.000	0.000	0.025
Install urinal retrofit kit	0.146	3.398	2.254	1.377	0.080	0.063	2.848	0.831	1.793
Install waterless urinal	0.000	0.032	0.000	0.000	0.000	0.000	0.139	0.000	0.000
Recycle process water	20.726	0.000	4.160	0.000	25.948	0.151	0.180	0.920	0.000
Reduce dishwasher loads	0.000	0.137	0.000	0.093	0.000	0.158	0.018	0.000	0.011
Reduce irrigation schedule time	1.996	2.136	7.695	6.046	0.044	3.523	10.903	1.764	5.394
Reduce water input	0.000	2.832	0.184	0.000	0.000	0.000	0.000	0.000	0.266
Remove garbage disposal	0.000	0.000	0.086	0.000	0.000	0.000	0.000	0.000	0.000
Repair leaks	0.000	0.344	0.000	1.536	0.121	0.164	0.084	0.000	0.872
Replace automatic shut-off nozzle	0.000	0.751	0.042	0.038	0.000	0.178	0.000	0.000	0.046
Replace faucet	0.000	0.349	0.000	0.092	0.000	0.043	0.020	0.000	0.086
Replace miscellaneous. Equipment & parts	7.140	0.826	0.252	0.000	0.000	0.040	0.270	0.000	0.211
Routine degreasing of water fountain	0.000	1.414	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Scrape dishes	0.000	0.324	0.161	0.053	0.000	0.135	0.012	0.000	0.000
Turn off equipment	0.000	0.000	0.000	0.044	0.000	0.010	0.000	0.000	0.000
Use groundwater	0.000	0.000	2.575	1.363	0.000	0.000	0.000	0.000	0.000
Use installed equipment	0.000	0.000	0.000	0.375	0.000	0.000	0.365	0.000	0.000
Total	33.628	33.026	47.654	34.588	35.371	27.681	33.638	24.500	28.994

Source: Adapted from Hagler Bailly Services (1997b). Table 6-4.

Table F.7 Identified water savings by institutional category and measure (% of annual total use)

Specific measure	Education	Government	Religious	Utilities
Adjust blowdown cycle	0.563	2.681	4.036	0.345
Adjust equipment	0.103	0.000	0.000	0.000
Change operational practices	0.003	0.000	0.000	1.126
Install automatic shut-off nozzle	0.009	0.000	0.000	0.000
Install faucet aerator	0.674	0.709	1.855	0.372
Install flow straightner	0.260	1.103	1.374	0.265
Install miscellaneous equipment & parts	0.235	0.000	0.000	0.000
Install new front loading machine	0.113	0.000	0.000	0.006
Install spray nozzle	0.000	0.008	0.000	0.000
Install toilet displacement device	0.000	0.000	1.370	0.000
Install toilet retrofit kit	0.821	0.000	1.800	0.000
Install ULF showerhead	0.263	0.430	0.587	0.415
Install ULF toilet	5.668	8.102	11.618	3.170
Install ULF urinals	0.239	1.382	0.000	0.000
Install urinal retrofit kit	2.581	0.823	3.320	0.828
Install waterless urinal	0.000	0.000	0.000	0.000
Recycle process water	0.000	0.000	0.000	7.916
Reduce dishwasher loads	0.000	0.042	0.056	0.000
Reduce irrigation schedule time	7.312	17.213	23.880	0.000
Reduce water input	0.000	0.000	0.000	0.000
Remove garbage disposal	0.002	0.000	0.000	0.000
Repair leaks	0.250	0.000	0.065	0.000
Replace automatic shut-off nozzle	0.006	0.000	0.043	0.000
Replace faucet	0.000	0.000	0.000	0.000
Replace miscellaneous equipment & parts	0.076	0.000	0.000	0.000
Routine degreasing of water fountain	0.000	0.000	0.000	0.000
Scrape dishes	0.007	0.000	0.000	0.000
Turn off equipment	0.010	0.000	0.000	0.000
Use groundwater	0.000	0.000	0.000	0.000
Use installed equipment	0.000	0.000	0.000	0.000
Total	19.195	32.492	50.002	14.442

Source: Adapted from Hagler Bailly Services (1997b). Table 6-4.

Table F.8 Reported implementation rates per CI category

Customer group	% of recommended measures implemented	% of potential savings realized
Industrial	35	19
Education	34	35
Hotel/motel	61	67
Retail/wholesale	48	61
Restaurants	36	29
Office buildings	41	63
Nursing facilities	17	15

Source: Jon Sweeten and Ben Chaput (1997). *Identifying the Conservation Opportunities in the Commercial, Industrial, and Institutional Sector. AWWA*. Table 6.

Table F.9 Conservation measures: implementation rates and water savings

General measures	Conservation measure	% of identified unit measures imple-mented	Imple-mented savings (ccf / lifetime)	% of identified savings implemented
Cooling	Change operational practices	100	500	100
	Reduce water input	100	14	100
	Adjust blowdown cycles	64	89,989	70
	Install miscellaneous equipment & parts	0	0	0
	Cooling subtotal	63	90,502	61
Irrigation	Reduce irrigation schedule time	72	127,795	68
	Repair leaks	50	210	9
	Install miscellaneous equipment & parts	0	0	0
	Irrigation subtotal	72	128,005	63
Kitchen	Use installed equip.	100	2,865	100
	Repair leaks	92	2,409	98
	Install faucet aerator	48	2,804	52
	Reduce dishwasher loads	71	372	50
	Replace automatic shut-off nozzle	32	4,564	32
	Scrape dishes	56	156	31
	Install automatic shut-off nozzle	42	4,290	28
	Replace faucet	45	3,720	27
	Install flow straightner	35	8,579	25
	Install miscellaneous equipment & parts	0	0	0
	Replace miscellaneous equipment. & parts	0	0	0
	Change operational practice	0	0	0
	Kitchen subtotal	42	29,759	32
Laundry	Recycle process water	33	16,750	14
	Install new front loading machine	0	0	0

(continued)

Table F.9 (Continued)

General measures	Conservation measure	% of identified unit measures imple- mented	Imple- mented savings (ccf / lifetime)	% of identified savings implemented
	Laundry subtotal	1	16,750	5
Other	Use installed equipment	100	1,580	100
	Install spray nozzle	50	5,040	97
	Use groundwater	50	561,495	91
	Install miscellaneous equipment. & parts	49	96,150	34
	Change operation practices	57	30,062	29
	Repair leaks	80	9,216	28
	Recycle process water	36	526,818	24
	Adjust equipment	38	1,980	20
	Turn off equipment	50	27	18
	Routine degreasing of water curtain	7	175	7
	Replace miscellaneous equipment & parts	48	16,745	1
	Reduce water input	25	171	0
	Remove garbage disposal	0	0	0
	Scrape dishes	0	0	0
	Other subtotal	45	1,249,458	23
Sanitary	Replace faucet	100	1870	100
	Repair leaks	82	21,474	92
	Adjust equip.	86	2,141	69
	Install ULF showerhead	64	155,945	64
	Install faucet aerator	57	65,968	60
	Install ULF urinals	71	106,972	56
	Install toilet displace device	38	731	50
	Install urinal retrofit kit	31	354,195	37
	Install ULF toilet	23	1,814,625	24
	Install toilet retrofit kit	27	61,555	20
	Install flow straightner	20	17,729	19
	Install miscellaneous equipment. & parts	4	210	2
	install waterless urinal	0	0	0
	Replace miscellaneous equipment & parts	0	0	0
	Sanitary subtotal	41	2,603,415	28

Source: Adapted from Hagler Bailly Services (1997b). Table 6-2.

Table F.10 Reported reasons for not implementing recommended measures

CI sector	Financial (%)	Scheduling (%)	Availability/ labor (%)	Imprac- tical (%)	No Interest (%)	Report not read (%)	Low savings (%)
Car wash	0	0	0	37	1	59	2
Eating & drinking places	33	3	18	19	8	15	5
Education	61	25	5	7	1	0	0
Government	41	2	3	1	52	0	0
Hospitals	42	25	2	0	0	31	0
Hotels, motels, & tourist courts	64	16	1	1	16	0	3
Industrial	63	6	2	17	6	6	1
Laundry, cleaning, & garment services	0	34	44	16	0	0	6
Nursing & personal care facilities	27	60	2	8	2	1	0
Offices	47	2	3	29	6	0	12
Others	23	0	4	23	0	49	0
Recreation	75	2	0	3	2	18	1
Religious organizations	6	69	17	5	0	3	0
Retail/wholesale	54	8	5	14	7	8	4
Trucking terminal facilities	51	23	4	10	0	3	9
Utilities	7	67	11	12	0	0	3
% of Total	53	16	4	13	6	6	1
Measures							
Cooling	11	15	3	13	59	0	0
Irrigation	39	6	5	2	19	30	0
Kitchen	31	35	6	8	7	13	2
Laundry	0	46	36	13	0	0	5
Other	68	3	1	16	6	5	0
Sanitary	46	24	5	11	5	7	2
Total	53	16	4	13	6	6	1

Source: Adapted/derived from Hagler Bailly Services (1997b). Table 5-5, Table 6-3.

SUMMARY

Identification of Conservation Potential

Billing records can be used for identifying the potential for water conservation among CI customers for a given water utility based on such characteristics of water use as:

- Degree of homogeneity of water use types (or composition of end uses) within a given CI category

- Inter- and intra-class variability of per account water use
- Total water use by category relative to the CI sector use
- Number of customers within category
- Presence of seasonal water use

Categories of CI users with high cross-sectional variability of usage rates and/or variability of usage rates throughout the year are likely candidates for conservation programs. Another important consideration is the number of customers within the category that have to be approached during program implementation. Categories with fewer users that account for a significant percentage of total water use are generally better conservation targets than categories with a large number of customers.

Conservation Experience

The information on the opportunities for water conservation described in this chapter can be summarized in terms the following findings and implications for the design and implementation of CI conservation programs:

- Some large-water-using categories have been ignored for water audits. Water audit programs need to include warehouses, correctional facilities, military bases, utility systems, and passenger terminals.
- Potential savings are in the 15 to 50 percent range, with 15 to 35 percent being typical. In addition, payback periods are between one and four years, and may normally be less than 2.5 years.
- Many ICI water users do not need to use potable water in all applications. Each customer and water use should be examined to determine if water of less-than-drinking-quality can be used or recycled on-site, or if reclaimed effluent could feasibly be used.
- Discussion of the successes and failures of other programs can provide insight. Cooperation between water, wastewater providers, and energy utilities is essential to demand management programs.

- Although nonresidential audits are becoming a more frequently employed conservation measure, documentation of programs are often not readily available.

In general, water conservation programs that have been implemented are rarely well documented and evaluated. Many available documents lack direct information for generalizing water savings. There is a need for more information on program costs, implementation conditions, and measurement of savings.

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ABBREVIATIONS

AD	audit data
AWC	average winter consumption
AWWA	American Water Works Association
AWWARF	American Water Works Association Research Foundation
BIG	business, industry and government
CCF	hundred cubic feet
CDA	conditional demand analysis
CFM	cubic feet per minute
CIEUWS	Commercial and Institutional End Uses of Water Study
CI	commercial and institutional
CIMIS	California Irrigation Management Information System
CII	commercial, institutional, and industrial
CR	concentration ratio
EPA	Environmental Protection Agency
ES	executive summary
ET	evapotranspiration
fpd	flushes per day
FS	field study
GAD	gallons per account per day
Gal.	Gallons
GED	gallons per employee per day
gpd	gallons per day
gpdc	gallons per day per customer
gpf	gallons per flush

gph	gallons per hour
gpm	gallons per minute
gpsf	gallons per square foot
gtd	gallons per toilet per day
GUOD	gallons per unit of output per day
hcf	hundred cubic feet
ICI	industrial, commercial, and institutional
kgal	kilo gallons (thousands of gallons)
MD	modeled audit data
med	medium
mgd	millions of gallons per day
M&I	municipal and industrial
n	number of observations or sample members
na	not applicable or not available
NAICS	North American Industry Classification System
PAC	project advisory committee
ppm	parts per million
r^2	coefficient of determination
REUWS	Residential End Uses of Water Study
sf	square foot
SIC	standard industrial classification

t	t statistic for hypothesis testing
TA	total number of accounts in the category
TDS	total dissolved solids
TGD	total gallons per day in the category
TUOD	total units of output per day
ULF	ultra low flush
ULFT	ultra low flush toilet
USGS	United States Geological Survey
yr	year

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