THE EFFECT OF CONSERVATION PROGRAMS ON THE QUALITY OF URBAN LAWNS

by

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ABSTRACT

Growing populations and a limited water supply have made water conservation a necessary part of municipal supply programs for most Front Range Colorado cities. This study was conducted to determine if intensity of conservation programs has an effect on the quality of urban lawns. Three levels of intensity (which include water price) were identified: aggressive; moderate; and passive.

Lawn quality was measured on a random sample of 209 lawns in seven northern Colorado cities: Greeley; Fort Collins; Broomfield; Longmont; Boulder; Aurora; and Lafayette. Color reference cards were used to determine the relative greenness of the lawn. Data were collected for each city during the summer seasons of 1985 and 1986.

The statistical tests and other observations contain trends suggesting that higher conservation intensity and water price result in lower lawn quality. The lowest-quality lawns were associated with cities using aggressive conservation intensity. However, there was little difference in lawn quality between the two lower levels of conservation intensity (moderate and passive), suggesting acceptable lawn quality can be expected even with a moderate level of conservation intensity and price.

CONTENTS

TABLES

Table

FIGURES

Figure

CHAPTER I

INTRODUCTION

A survey of urban lawns was made in several Front Range, Colorado cities (Figure 1.1) during the summer of 1986. The reason for the work was to determine the effects of various water conservation policies on the quality of urban lawns.

Lawn quality was measured using reference cards to determine the percentage of green vs. brown in the lawns. Lawns that had a higher percentage of green were given higher scores on a scale from one to ten. The range in quality of each lawn was recorded to reflect the areal consistancy of each lawn in its quality rating.

Conservation programs were judged according to two basic criteria. The first was economic, that is, the price of water. The second was the emphasis each municipality put on encouraging water users to conserve. Items such as metering, restriction policies, community workshops and classes, and city ordinances requiring conservation were indicators of a city's commitment. Cities were catagorized into three

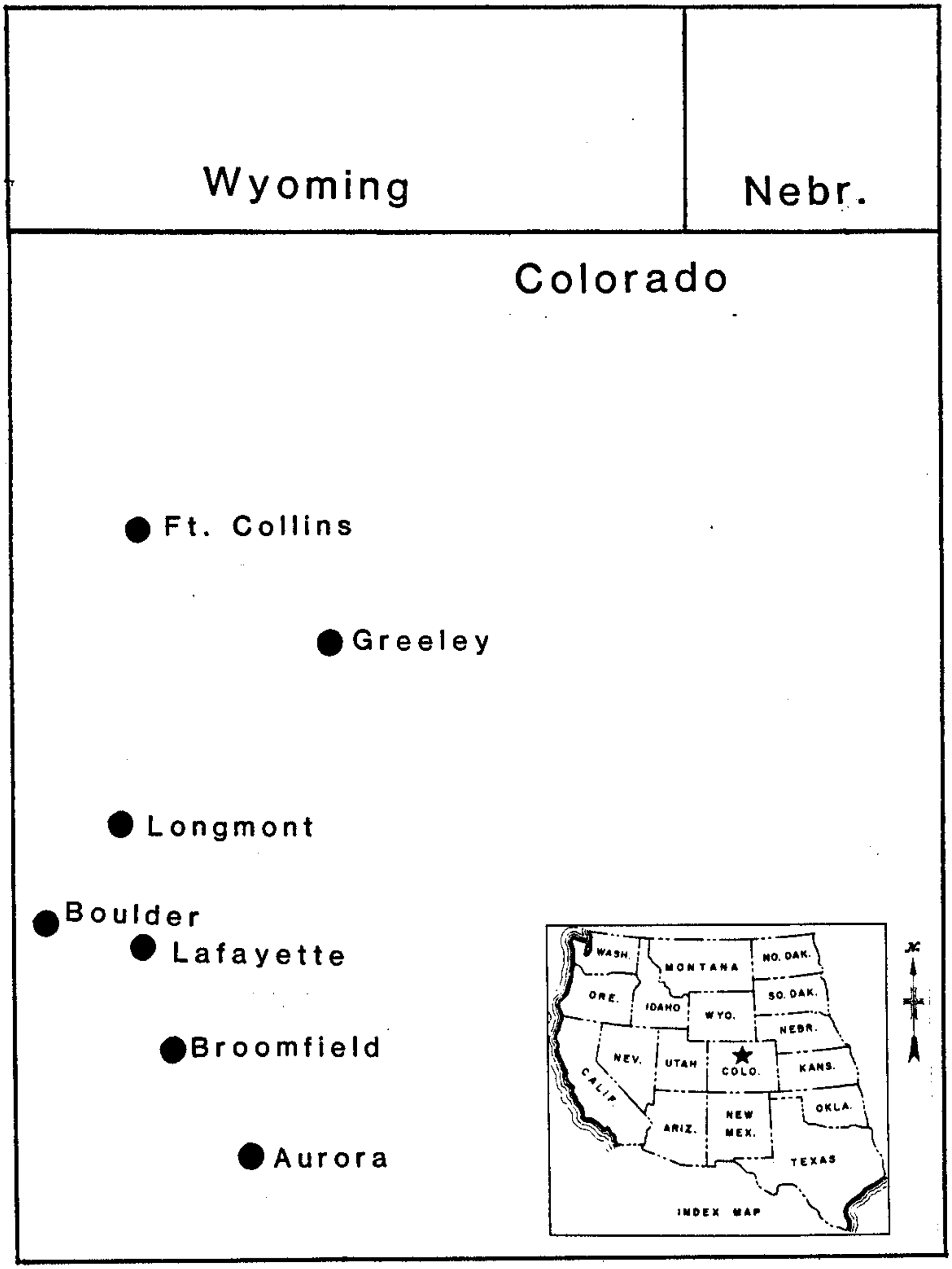

FIGURE 1.1 Map of Colorado Front Range showing cities that were surveyed.

groups according to their conservation programs. Finally, results of the survey were analyzed in Chapter V using nonparametric methods. The results show that there is little difference in the average lawn qualities of the cities surveyed.The results also show that high water cost and poor maintanance habits are the biggest deterrents to green lawns.

The importance of green lawns should not be underestimated. In Colorado, where water supplies are never expendable, over 50% of the treated water goes to outdoor use. Most of this water is applied to urban lawns during the late spring and summer months, causing a strain on urban water supply systems. Conservation measures have been developed in recent years to reduce the amount of water consumed by the growing population. Some cities are hesitant to implement water conservation measures due to fears that brown lawns will make their city a less desireable place to live. Some water customers may be hesitant to practice conservation due to fears that brown lawns cause decreased property values and social status. While these consequences may result from brown lawns, the fear that conservation causes poorer quality lawns is without justification, according to this study.

This thesis suggests that good lawn quality can be achieved along with water conservation and that conservation education leading to good maintanance habits can actually promote high quality lawns.

CHAPTER II

REVIEW OF LITERATURE

Introduction

Due to the recent growth of urban populations and the finite amount of water available for public use, it has become almost universally accepted that conservation of water is both a necessary and feasible consideration in water supply programs. A great deal of research has been done investigating the various ways to conserve water. Additional work has been done determining turfgrass water requirements and turf quality for various species of grass, most notably Kentucky bluegrass. A review of these results is in order to provide adequate background for this thesis.

Residential water use accounts for about 65% of total treated water in typical cities and metropolitan areas (Hanke and Mehrez, 1979; Martin et al, 1984; Ellinghouse and McCoy, 1982). With the growth of cities and the continual conversion of agricultural land to urban use (requiring treated water), overall urban use will continue to increase. Table 2.1 shows the use patterns by class of customer

TABLE 2.1
USE PATTERNS BY CUSTOMER CLASS

Region	Residential	Commercial	Industrial	Total
Tuscon	76%	17%	7%	100%
Boulder	72	9	9	90*
California	68**	10	18	96
United States	35	23	14	--

* 10% System losses
** Includes system losses

Adapted from: Flack (1982), Martin et al (1984).

for several areas.

Since the largest use class is residential, the largest potential savings can be realized in the residential sector. Much work has been done in estimating domestic (indoor) use. Table 2.2 shows a summary of various results from the literature.

TABLE 2.2
PER CAPITA DOMESTIC WATER USE

Reference	Total (gpcd)
Linaweaver, et al (1963)	64.0
Reid (1965)	59.0
Baily, et al (1969)	63.8
Kreissl (1971)	63.8
Felton (1974)	44.5
Nelson (1975)	76.0
Sharpe (1975)	65.0
Metcalf and Eddy (1976)	60.0
Joseph (1982)	70.0
Maddaus (1986)	77.0

Adapted from: Weakley (1977)

The more recent studies appear to estimate higher values than earlier studies and this can possibly be explained by the increase in in-home water using appliances such as washing machines and dishwashers. Overall in-house use can be considered fairly constant across the country (Linaweaver,1967). Conversely, outdoor use is quite variable from region to region and even within similar geographical regions. Outdoor use is affected by price, metering, climate, residential density, and economic status of user. Average values range from 160 gallons per day per dwelling unit (gpd/du) for metered homes to 420 gpd/du for unmetered homes (Linaweaver, 1967).

Indoor Use

Indoor use can be reduced by the use of various combinations of water saving devices in the bathroom, water saving appliances, leakage reduction, building code modifications, pricing strategies and pressure reduction (Weakley, 1977).

Precise amounts of indoor water that can be saved by any of these methods are not reliable. Flack (1982) estimates that an 11% reduction can be realized if potential savings from each method are added. Hoag (1981) warns, however, "Estimates of the reduction in water use associated with each alternative program cannot be a simple sum of the savings for individual practices". Because of this, actual amounts of water saved are probably less than those reported in the literature (Maddaus, 1986).

Water saving devices for the toilet produced a 39% reduction in the amount of water used in toilets (Weakley, 1977). Water saving devices for the shower reduce use by contriction of flow. Since there is much variation in personal habits estimates are hard to obtain. A North Marin County utility estimates a savings of 7.5 gpcd. Using an estimate of 20 gpcd under normal use patterns (Flack, 1981, p.8), a savings of 37.5% is realized. Reduction in the bathroom could total 30% and with bathroom use being 75% of indoor use (Weakley, 1977) a savings of 23% is possible.

Despite these figures, retrofit structural changes such as these accounted for only a small reduction in water use during a severe drought in Northern California (Martin, 1984). It was concluded that when crisis was perceived as over by water users, use levels rose to pre-crisis levels. Most likely, structural devices were removed. As consumers accept the idea that conservation must become a way of life, structural devices could achieve long term savings, the study suggested. Consumers seek out changes that will require no daily conscious thought such as toilet dams or landscaping changes (Martin, 1984). This concurs with a more recent study done by Baumann. He found that only technological (structural) measures had any effect on water use. Behavioral measures (practices of users) had no effect, and this even though behavioral measures were more highly preferred by consumers (Baumann, 1986). In a recent nationwide study (Maddaus, 1986), total indoor reduction was found to be 23.3%. These recent results are based on actual use data that should be considered more reliable than "a priori" estimates.

Outdoor Use

Whereas saving indoor water does reduce peak demand and allows smaller system capacity, it does not save much water. Water not used indoors would just continue downstream instead of being recycled back into the stream through the city's treatment plant. The only way to achieve large savings is by reducing consumptive use. The predominant urban consumptive use of treated water is urban irrigation. Linaweaver (1967) and Williams (1975) report that 40 to 50% of water treated annually is applied to urban lawns. In western cities during the summer the percentage can approach 70%. Table 2.3 highlights the estimates of summertime percentages found in the literature.

As Flack concludes, "Peak water demand rates are primarily the result of sprinkling demands in the more arid regions of the country" (Flack, 1982, p.10).

In at least one Colorado study, outdoor use other than lawn watering was considered negligible (Danielson, 1979). In the Front Range climate where there are relatively few swimming pools this is a safe assumption. Therefore, the reduction of outdoor use is fundamentally dependent upon the reduction of lawn watering. Several methods to reduce this use have been studied.

TABLE 2.3
PERCENTAGE OF TREATED WATER APPLIED TO URBAN LAWNS
(SUMMER USE)

Reference	Percentage	Location
Aurasteh (1983)	61%	Logan, Utah
Danielson, et al (1979)	70%	Colorado Front Range
Flack (1982)	3-70%	Various
Pochop & Borrelli (1979)	80-85%	Wyoming

Metering

It is clear from previous studies that metering homes has a profound effect on lawn sprinkling use. In the Johns Hopkins study of 1967 it was reported that the difference in outdoor use between metered and unmetered homes is 260gpd/du. The amount of outdoor use is determined by subtracting the average total winter use from the average total summer use. Since indoor use is considered constant from season to season and since no outdoor use is assumed to take place in the winter, the difference is the outdoor use. This calculation is called the winter base rate method.

Ellinghouse and McCoy (1982) suggested that a 30% reduction in total use could be achieved by metering all residential taps. They reported indoor use as equal between Ft. Collins (unmetered) and Boulder (metered) while the outdoor use of Ft. Collins was nearly double. In a study of nine Colorado Front Range cities, DiNatale showed that the average summer use for the metered communities was 29% less than for the unmetered communities over the same time period (DiNatale, 1981). Water use in Boulder, Colorado dropped 36% after meters were installed (Hanke, 1969). Weakly reports that metering has the effect of reducing total demand by 21%, lawn sprinkling by 31%, and return flow by 29% (Weakley, 1977). Clearly a lack of monetary value (i.e. flat rates) placed on water supports and perhaps encourages excessive use. In 1964 it was reported that more than 90% of all water services in the U.S. were metered (Flemming, 1964). Yet, many large cities such as Denver and New York City remain, for the most part, unmetered.

Restrictions

The other main thrust of outdoor conservation is a restriction-in-use program. Restrictions on water use can be made either for certain periods within a day or certain days in a week. Hanke and Mehrez (1979) classify restrictions in two ways: 1) light restrictions - a limit on the number of hours of operation or a ban on outdoor sprinklers, and 2) heavy restrictions - a ban on all outdoor water use. The purpose of light restrictions is to reduce peak use while the purpose of heavy restrictions is to reduce total volume of water used. The nature of light restrictions has historically been to "knock off" the peaks by attenuation. Water use was reduced by 14% in Perth, Austrailia using restrictions (Hanke and Mehrez, 1979). The Denver Water Department reported that total water usage was reduced up to 16.5% in June of 1978 due to restrictions but was actually 9.5% higher in September of 1978 than the estimated unrestricted demand (Flack, 1982). Greenberg reports that the Denver water customers actually used more water over the summer season with every third day restrictions but, since peak use was reduced, it remained a favorable policy (Greenberg, 1981). Attenuating the peaks creates less stress on the system and thus delays or even cancels the need for expensive system expansion. Greenberg explains the findings in this way:

> Daily and/or hourly restrictions have been proven to be most effective to reduce the peak demand although with appropriate and continuous public education overall demand may also be reduced. (Greenberg, 1981, p.80)

It would appear that public education leading to behavioral changes was the cause for total water savings under restrictions. In another study, an 18% reduction in outside use under restrictions was achieved with only a 5% increase in use level when the restrictions were relaxed. Greenberg attributes the savings to education of the public (Greenberg, 1981). Restrictions on other outdoor uses such as filling swimming pools and washing cars have been made although restrictions on lawn sprinkling are most common in times of drought (Flack, 1982).

On a final note, restrictions are less desireable that metering in the sense that they inconvenience the water user. Other methods are designed to operate without the regular conscious decision of the water user which minimizes inconveniences to him (Flack, 1981).

Agricultural Practice

Another, less frequently used way of conserving water is change in urban agricultural practice. Gentler slopes decrease runoff time and increase contact time. Shade trees lessen evapotranspiration from the lawn but nulify the effects due to the tree's evapotranspiration. The proper density of nutrients in the soil will enable grass to stay healthier (greener) longer without being watered (Nelson, 1976; Danielson et al, 1979).

The most drastic measure to reduce outdoor consumption is the removal of lawns. While this may be objectionable to some, 20% of residents were willing to remove front yard lawns and 15% were willing to remove backyard lawns in Tucson, Arizona between 1976 and 1979. Since front yard removal was favored over backyard removal, social conformity or status of a "front" lawn appears to be less important than the functional utility of a "back" lawn (Martin et al, 1984). Asumming that very few would be willing to remove both front and back lawns, well over 30% were willing to make this drastic change to conserve water in Tucson.

The total removal of urban grass areas is generally considered to be aesthetically detrimental. Green vegetation provides a cooling effect in an urban environment that would be substantially depleted if all lawns were removed. This, in turn, would increase the demand on artificial forms of cooling (air conditioning) which puts an increase on power demands. Since power generation consumes water for cooling, less water is actually saved; only its use is relocated. An alternate vegetation scheme providing adequate cooling effects and yet consuming less water is necessary to reduce total consumptive use to the system (Nelson, 1986).

Public Acceptance

Although one study claims, "It is not true that public approval of conservation techniques is necessary to their successful use" (Martin et al, 1984), having public approval is deemed necessary to maximize benefits from a conservation program. Hoag counsels,

> It is advisable to build into the planning process the time and techniques required to consult with community leaders and with interest groups having major interest in a water conservation effort. (Hoag et al, 1981)

Greenberg made a survey of public receptivity toward conservation policies in various Northern Colorado communities. Among her findings were a 75% preference toward metering over other techniques in drought areas and an 81% opposition toward restrictions in normal years. People did prefer restrictions over price increases for times of summer high demand. About 95% of town managers and 75% of respondants approved of restrictions as a good method of dealing with low water supply. No systematic relationships were found between opinions on restrictions and type of community (flat rate vs. metered, urban vs. rural) or socio-economic variables (education, income). She also found that lawn size limitation is not popular among consumers or managers and that many towns even require that 60 to 70% of a lot be in vegetation (Greenberg, 1981).

Hoag suggests that voluntary methods may not be sufficient to reduce water use by more than 10 or 15% (Hoag et al, 1981). Perhaps the correlation lies not in voluntary vs. mandatory programming but in understanding of the severity of the drought. Voluntary programs are not very likely to be pursued in a severe drought situation. Yet, there is much to show that the success of conservation programs is dependent upon the drought being perceived as severe (Russell et al, 1970). Consumers were willing to undergo necessary costs as long as they were convinced of the seriousness of the situation (Bollman et al, 1977). Research also shows that homeowners will replace existing landscaping with more drought tolerant water saving vegetation types only in cases of very limited water supply or high water costs (Hoag et al, 1981).

Bruvold classified water conservation programs as mild, moderate or rigorous. While the moderate group achieved and in some cases exceeded its goals, the rigorous program exceeded its own goals and was the most water conscious. He also notes socio-demographic variables had little effect and concluded that perception of the consumer as to the severity of the shortage is the key attitudinal factor affecting conservation program effectiveness (Bruvold, 1978). Greenberg reports that after a severe drought year in Marin County, California, 98% of the people had changed water use habits the following year to conserve water.

Clearly, public education is the catalyst that increases the savings in a water conservation program. Martin et al (1984) summarizes by saying that significant reduction requires:

1)Users seeing that it is in their own self interest to use less water and,

2)Users realizing that their personal role is vital in conserving water and,

3)Users hearing continual reinforcement and exhortation about the advantages of reducing consumption.

He reports "the demand for water used outdoors is largely the result of a preference for green lawns." (Martin et al, 1984, p.89) One might think that to reduce outdoor water use would result in the reduction of the quality (greenness) of urban lawns. Research has shown, however, that water is usually applied to lawns in excess. The Stata of California estimates that as much as 20% of water applied to lawns is excess (Flack, 1982). In Utah there was little correspondence between plant water needs as determined from lysimeter tests and the amount of water applied (Aurasteh, 1983). Pochop and Borrelli found similar results in two Wyoming cities stating that, "most homeowners have little idea how much excess water they are applying." (Pochop and Borrelli, 1979, p.18) Aurasteh estimated application efficiencies of 30 to 37% depending on the type of watering system. These are low efficiencies when compared with normal agricultural values.

In a New Mexico study it was found that urban landscapes in Las Cruces used 50% more water than was needed to meet consumptive use as calculated by the Blaney-Criddle, Thornthwaite, and Penman methods. The conclusion was that land owners lacked knowledge (or didn't feel the need) to use water in direct relation with plant needs. In that same study landscapes were catagorized as green and intermediate green. Green landscapes had an average of 56% more vegetation than intermediate green landscapes yet received 100% more water. Cultivation of an intermediate green (vs. green) landscape does suggest some conservation consciousness but even these landscapes tended to be overwatered. When water use on a public university campus was cut back 47% the grass maintained good health and esthetic qualities but difficulty was encountered changing the habits of the maintanance crew (Cotter and Croft, 1974).

Several structural solutions are offered in the literature. Hoag et al (1981) reports that automatic sprinkling systems would decrease the tendency to overwater or to water at a rate greater than infiltration rates. He estimates a 20% maximum reduction. Drip irrigation systems are an alternative for border plants, trees and shrubs. These systems can produce an efficiency of up to 90% and could reduce outdoor use by 25 to 50% on the applied area (Hoag et al, 1981). It was earlier noted that lawn sprinkling was reduced by 36% when meters were installed in Boulder. This was a reduction to levels approximately equal to consumptive use levels of the lawn (Flack, 1982).

Decreasing the area of lawns is a trend in many western cities. This will provide a reduction in water consumption, but it does not deal with the problem of wasting water. As in many situations, forethought provides solutions. As many as ten years ago Cotter and Croft (1974) found that planned yards used less water. They concluded that it was possible to retain an esthetically pleasing landscape and still have low water consumption. Danielson et al (1979) suggest that watering only when the lawn requires water rather than on a regular basis promotes efficiency and healthier lawns and leads to water savings.

Lawn quality has been studied but comparisons are hard to make due to the subjective nature of the measurement. Within a study a relative measure of quality can be made, however. In most studies, quality is determined by observation (Pochop and Borelli, 1979; Danielson et al, 1979). Color, grass thickness, presence of dry patches and presence of weeds have all been observed. None of these are absolute indicators of lawn health but they probably are good indicators of what the lawn waterer responds to.

Aurasteh (1983) has shown that quality varies with relative evapotranspiration (ET). Relative ET is the ratio of actual ET by the plant to the potential

ET as determined by calculations. For a given lawn, ET will vary with temperature, humidity, duration and intensity of sunlight, wind speed and soil condition (Cotter and Croft, 1974). Water use on lawns is a function of maximum temperature and rainfall as well as the socio-economic factors earlier mentioned (Hanke and Mehrez, 1979; Howe and Linaweaver, 1967). Aurasteh's correlation coefficient between water applied and quality was in the range of 0.9. In a Wyoming study, lawns with water application to potential ET ratios between 1.0 and 1.25 averaged the highest quality (7.2 on a scale of 10). When the ratio was less than 1.0, quality of lawn dropped to 6.1. More interesting is that when this ratio was greater than 2.0 quality dropped to 5.8. This may be due to excessive leaching of vital nutrients but is probably an indicator of poor lawn maintenance habits (Pochop and Borrelli, 1979). A study was done in Colorado comparing the quality of bluegrass lawns in two towns. Color was the measure of quality, 0 being all brown and 10 being all green. Reference cards (photographs) ranging from 0 to 100% green were prepared to give as little subjectivism as possible in quality measurement. Scores of 8, 9, and 10 were barely distinguishible from each other. One town was on a metered system while the other was on a flat rate system. The lawns were comparable in a normal year but the flat rate lawns were 25% greener (5.9 to 7.4) in a dry year. Within the flat rate city there was a negligible change in quality from a drought year to normal year, while in the metered city there was a 20% increase (5.9 to 7.1). The lowest irrigation rate in the flat rate city was sufficient to maintain high quality lawns and additional water had little effect. In the metered city the relationship between lawn quality and irrigation rates had a significant positive, linear slope. It was also determined that lawn size and age of home were unrelated to lawn quality (Danielson et al, 1979).

In an Arizona study it was shown that several Bermuda grasses will use excess water for consumptive use when available. Acceptable quality lawns can be grown using 50 to 80% of pan evaporation rates depending on the quality desired (Kneebone and Pepper, 1979). Danielson et al found in a 1981 study that irrigation of bluegrass can be lowered to about 70% of maximum ET without loss of quality.
Fertilizer applications have some effect on bluegrass quality but only in conjunction with water use. Aurasteh (1983) found that fertilizer did not significantly improve grass quality in low water situations. Danielson et al (1981) found that for a

given ET rate lawns with adequate nitrogen (fertilizer) had a higher quality. He also found that adequately fertilized lawns were more drought tolerant and returned to color faster after a brown dormancy than did inadequately fertilized lawns. Grass with a nitrogen deficiency decreased linearly in quality with a decrease in water. Adequately fertilized grass showed only slight decrease in quality with a decrease in water until irrigation was below 70% of ET, whereupon quality quickly fell (Danielson et al, 1981). It is clear that lawn quality correlates directly with available water and indirectly with other factors such as nitrogen availability and soil type.

Alternatives

With the growing awareness of the need fer water conservation, there has been an increased interest inat alternatives in urban agricultural management. Both the water savings and the quality of turf can be preserved under a well managed system. Flack observes, "Horticultural changes in residential lawns can drastically affect a municipal utility system's peak water usage." (Flack, 1982, p.27) From the standpoint of quality Danielson concludes, "When the need to conserve requires that less water be applied than the vegetation can efficiently use...

proper management can minimize the loss of quality in turfgrass." (Danielson et al, 1981, p.46) Three modes of changing water use by urban lndscapes have been cited: lawn watering methods, landscaping practices and plant types. Having looked at changes in lawn watering methods, the two remaining modes will be reviewed.

Landscaping changes have been among the least considered alternatives in the effort to save water. Increase of shaded areas and fertilization, and altering contouring and mowing practices can all affect water usage. A Northern Colorado study (Danielson et al, 1981) showed that water use increased linearly with an increase in direct solar radiation. Shade trees transpire more water than grass areas and cannot be used to decrease water use. Very low water using trees or buildings can be used to provide shade. Contouring has the effect of reducing runoff and prolonging infiltration times, leading to more efficient irrigation As has been noted, fertilization leads to a more drought hardy plant and can reduce the owners urge to over-water. Higher mower settings had the effect of raising water use by 15% over shorter levels when water was plentiful. This was due to the increased surface area of the blades of grass causing greater adsorption of the advective energy used to transpire water and not a change in function of the plant. Shorter grasses showed less tolerance to limited irrigation (Danielson et al, 1981).

Low water using plants are also a means of decreasing consumptive use of water. Since lawns are the major water users in most yards, low water using grasses could be a substantial contributor to water savings. Studies have shown that cool season grasses such as bluegrass use more water than warm season grasses (Kneebone and Pepper, 1979). Whereas exact measurements are hard to make, Danielson et al (1981) was able to show that Bermuda grass used 20% less water during the hot summer months but turned brown much earlier in the fall than bluegrass. Some other alternate species that requireless water than bluegrass are buffalo grass, blue grama, sideoates grama, and yellow bluestem (Uno, 1974).

Again, the weakest link in this water saving plan is public acceptance. Flack states that the degree to which the public accepts these alternate species will determine the amount of water that will be saved. Two reasons that exist for limited acceptance are the high cost of seed and the non-availability of sod. (Flack, 1982) Recently, more alternate sods have become available but are still not "pushed" by architects or nurserymen. The uncertainty involved in something as expensive (and visible) as the front lawn is probably not an acceptable risk.

Bedding plants provide another area for alternate species. Rondon (1980) showed that redesigning of residential landscapes to include more native and drought resistant plants can reduce water demand. A study in California showed that townhouse projects with a drought tolerant landscaping theme required 40 to 60% less water per year than themes emphasizing normally used ornamental plants (Nelson, 1986).

In the last five years the Xeriscape program has been developed by the Denver Water Department and the Association of Landscape Architects of Colorado. This program studies and promotes the conservation of water through the use of alternative plant use and landscape design.

The need for urban water conservation for urban residents focuses on outdoor use. This review has shown that a reduction of water usage is possible through the reforming of watering and landscaping practices and that impairment to lawn quality can be held to a minimum. Studies do show that the quality of grass is directly related to the application of water. But, studies also show that through proper management and reduction of waste, degradation of lawn quality can be held to a minimum.

CHAPTER III

PROCEDURES

Methods which fairly measure and evaluate lawn quality and conservation practice data are required to determine the relationship between the two parameters. This chapter deals with procedures regarding fair data collection and appropriate use of statistical analysis.

Data Collection

Data was collected in two ways. Water conservation policy data was obtained by mail. A standard letter was mailed to each city's appropriate office. The letter asked for specific items regarding the city's water conservation program and requested that any additional pertinent information be sent. Request was also made for an opinion on the success (effectiveness) of the conservation measures.

Responses varied in volume and enthusiasm and it was felt that this variation would be an accurate indicator of the role of water conservation effort by each city. The assumption was that the more enthusiastic responses would come from the cities with more deeply developed and heavier emphasized conservation programs. Information from the one city that didn't respond had to be pursued through a personal interview. The same specific questions were asked and a chance to talk about additional programs and opinions on effectiveness was offered. Finally, all data was compiled and each city was evaluated on its programs. Special emphasis was given to the incentive and aid given to the water user by the city to conserve through structural, educational and economic means. The results of these findings are given in the next chapter.

The other half of the data collection required determining the quality of lawns in each of the cities. The basis for the ratings was the percentage of green vs. brown in the lawn. These determinations were made using reference cards developed by Danielson et al at Colorado State University (1979). Eleven photographs, ranging from 0 to 100% green in 10% increments are shown in Figure 3.1. The alternate color to the green is brown, matching the color of unhealthy or dormant Kentucky Bluegrass. A corresponding rating of 0 to 10 was assigned to each. These cards were taken into the field and compared

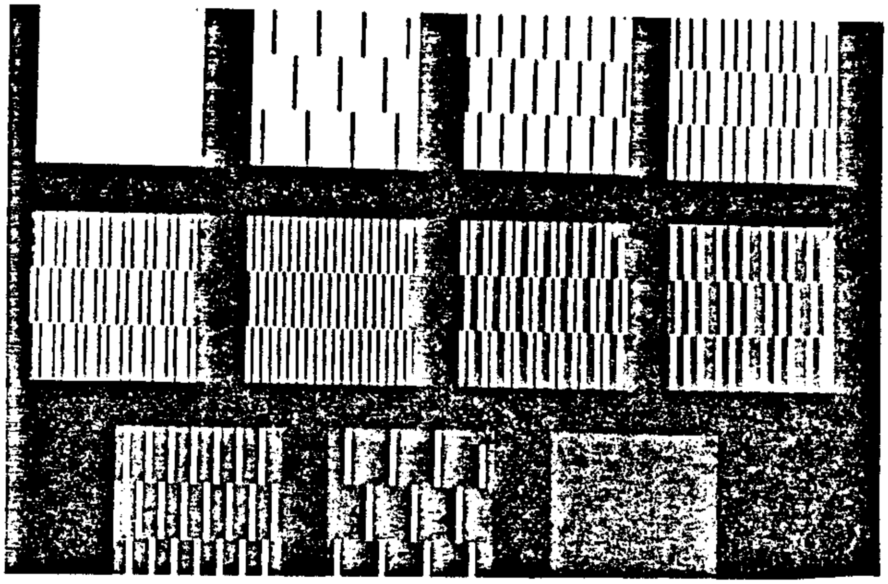

FIGURE 3.1 Green and brown (tan) color cards for evaluating lawn quality, ranging from 0 to 100% green in 10% increments.

with each front lawn of randomly selected homes. Since many lawns were patchy in their percentage of green, an average for the entire lawn was estimated. The range of each lawn (maximum score to minimum score) was also recorded.

During the testing, two seperate teams made measurements. The measurements did require some estimation so it was important that biases in evaluating the lawns from the cards were equal if not non-existant. To ensure this, one member from each team did the survey of the first city together. Ideally, differences in quality measurements resulting from estimating biases could be held to a minimum in this way.

A sample size of 120 was taken randomly from a list of water customers from each of the cities. The most important aspect of randomness was to insure that all data did not originate from a certain neighborhood or section of town. The sample was narrowed to 30. Good areal distribution within each town was the basis for the selection of the thirty lawns. Figure 3.2 shows a typical example of the random selection pattern. Some question may arise as to whether the sample size was large enough. The possibility of very large samples was eliminated by the constraints of manpower and time since it was important that all data be

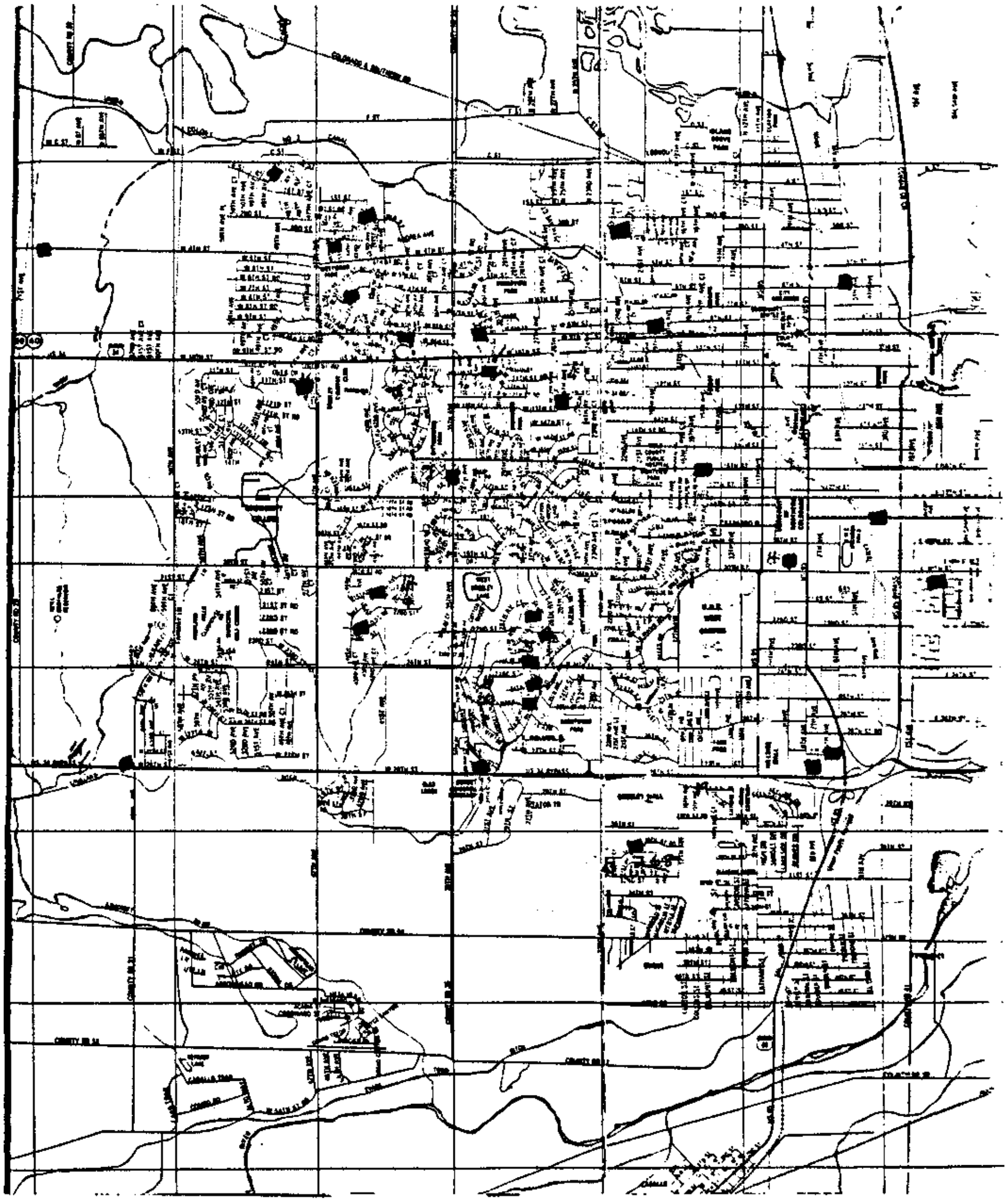

FIGURE 3.2 Typical areal selection pattern for lawn survey.

gathered in a short period of time. A size of thirty per city was chosen to satisfy statistical method requirements.

The final parameter that could effect the outcome of the data was the climate. As was mentioned above, the data needed to be gathered within a short period of time. This was to limit variations in precipitation, daytime temperatures and ET. By gathering all the data quickly, these factors could be assumed constant. The weather patterns in the weeks preceeding the survey also had an effect on the quality of lawns. Since high precipitation or low ET values would tend to reduce the amount of water required by irrigation, it was important that the survey be done following a relatively dry, hot period. If irrigation needs were low, conservation policies regarding urban irrigation would be of little concern. It is only when lawns are stressed by the lack of natural available moisture that the effects of reduced watering caused by conservation can be observed.

Figure 3.3 shows the precipitation and ET amounts for the three weeks preceeding the survey. This data is for the Denver metro area and did not differ substantially in the cities not in the metro area. - The days prior to the

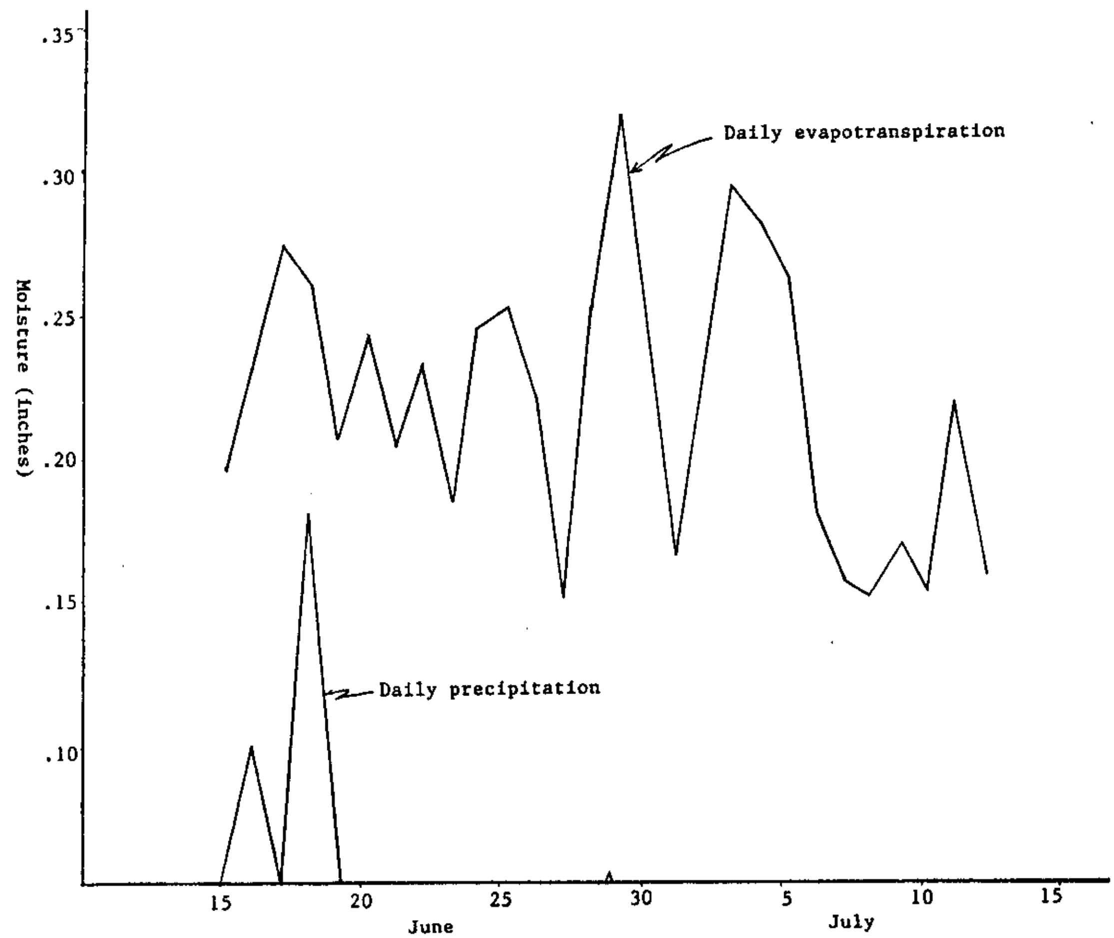

FIGURE 3.3 ET and precipitation amounts for the weeks preceding the survey in the Denver area.

survey were characterized by high temperatures, high ET rates and low precipitation. This condition resulted in lawn quality to accurately reflecting water applied from irrigation. There was a slight cooling trend immediately preceeding and during the survey but this bit of relief came too late to affect any measureable change in lawn quality. Overall weather conditions were ideal to obtain data, unhampered by climatic variation during the July 8 through July 12 (1986) survey period.

In addition to the lawn rating, an overall appearance rating was taken for the front yard. The purpose was to obtain some idea of the landscaping effort of the homeowner. There may be some error in crediting a nice appearing yard with good lawn maintanance habits but it is probably a good measure. In this study correlations between lawn quality and lawn maintainance habits were made

Statistical Methods

The final subject of this chapter deals with the statistical analysis used to evaluate the data. The normality of the data could not be justified prior to data collection so a large sample (at least thirty observations) was chosen from each city. This would allow tests designed for use with normal populations to be used with slightly off-normal populations. It was hoped that the distribution of the data would be in either of these two forms. In the case where the data were more than slightly off-normal, nonparametric methods would have to be used. The methods that were employed included the Kruskal-Wallis test, the Spearman Rank test, multiple correlation tests, and the Wilcoen two sample test. These methods all rely upon ranking the thirty lawns according to their lawn quality scores. By determining the arithmetic mean of the quality ratings of each city, cities were ranked to discover correlations with other variables. For a complete discussion of these methods of nonparametric rank comparisons see Walpole and Myers (1985) and Noether (1976).

CHAPTER IV

DESCRIPTION OF CITIES' PROGRAMS

A city's water conservation program will depend on the type and amount of expected water use, the regional climate and, most importantly, upon water available for supply. Because these factors vary, different conservation programs are used in each city. Following, is a description of the conservation program of each city of this study.

Aurora

Aurora has one of the most aggresive programs in the metro Denver area. Aurora is 100% metered. Water costs for the residential user are $1.27 per thousand gallons (ptg) plus a constant monthly charge of $2.52 for a 3/4" meter. City code prohibits the waste of water punishable by a fine up to $100 and suspension of service for three time violators. Unique to Aurora, and certainly the most widely felt of its measures, is the code limiting the size of urban lawns. A permit must be obtained before new lawns are installed and before existing lawns are enlarged. Table 4.1 shows these limitations by lot area.

TABLE 4.1
SUMMARY OF AURORA'S LAWN SIZE LIMITATIONS

Lot Size	Maximum Lawn Size
Up to 7000 sf	2000 sf plus 30% of remaining area
7000 to 17000 sf	3500 sf plus 15% of remaining area (maximum 5000 sf)
More than 17000 sf	50% of non-hard surface area

The code requires that soil under lawns be "prepared". City code also requires that low flow shower heads and toilets be used in all new and remodelled construction.

Summer time public education for the Aurora community emphasizes low water use landscaping, efficient use, Xeriscape workshops, lawn contests and voluntary adherance to the Denver Water Department's third day watering plan. School education programs have been in effect for three years. The effect of Aurora's public education program seems to be a greater conservation consciousness than would otherwise be expected. No precise data were obtained but there seemed to be a greater percentage of homes in Aurora showing evidence of conservation effort. An increased frequency of homes using rock or wood chips for ground covering and low water use plantings is evidence that supports this conclusion. This awareness is due, at least in part, to mandatory lawn size limitations. The permit system reminds every homeowner of conservation as plans are made for landscaping.

Lafayette

Lafayette is a small, predominantly residential community northwest of Denver. There is little agricultural or commercial development within the city limits and industry is virtually nonexistant. Lafayette achieves its water conservation in an entirely different way. In contrast to Aurora's emphasis on educating and assisting the public with conservation, Lafayette's plan is less cooperative. There are no school education programs, no community workshops, no landscaping ordinances and no emphasis on mandatory or voluntary watering restrictions. Lafayette achieves its conservation of water through an inverted block rate structure. The city's entire water conservation plan relies upon the consumer's reluctance to pay premium prices for a green lawn.

All residents inside city limits pay a flat monthly charge of $6.25 (residents outside the city pay $12.50) for a 3/4" meter. Table 4.2 shows the inverted block structure that applies to all users on Lafayette's system.

Not suprisingly, city officials say that water bills over $100 are not uncommon. They also report that peak water use is in June with a decline in July and August after June bills have been received.

Broomfield

Broomfield has a well developed, but less aggressive plan than Aurora. Watering between 7pm and 8am according to the Denver Water Department (DWD) every-third-day plan is encouraged but not mandatory. During 1980 and 1981 these restrictions were mandatory so most residents are at least aware of them. Public information is conveyed through newspaper articles and special city-wide programs such as Drinking Water Week. Broomfield is 100% metered with a constant rate structure. A monthly flat fee of $4.75 plus $1.52 ptg is assessed to all single family residences.

Longmont

Longmont's program is somewhat more intensive. City code includes an ordinance against wasting water to be enforced by a conservation officer responding to

TABLE 4.2
WATER RATE STRUCTURE FOR LAFAYETTE

Gallons Per Month	Cost, Per 1000 Gallons
Up to 5000	$1.25
5000 to 10000	$1.60
10000 to 15000	$2.10
15000 to 20000	$2.80
Upwards of 20000	$3.80

complaints. Service may be shut off after two warnings. Third day morning and evening watering restrictions are encouraged but not mandatory. The city promotes school and civic group education programs and holds Xeriscape workshops for the community. The DWD's ET rate is published in the daily paper. Longmont is only 39% metered but meter installation is mandatory on all new construction and on existing homes within 45 days of sale. Failure to meet metering ordinances can result in a $300 fine. Flat rates are based on number of bedrooms, shower/bathtubs, and toilets. Metered rates are $1.30 ptg for residents inside city limits and $1.95 ptg for those outside the city. One flaw in Longmont's rate structure is that flat rate customers often pay less per month than metered customers.

Greeley

Greeley's programs appear to be more aggressive but, in fact, are not very restrictive. Greeley does have a mandatory watering schedule based on every-other-day watering. Watering is not allowed between 1pm and 5pm for all private residences and churches. Violations carry $10, $25, $50 citations for first, second and third offenses, respectively. Public education is handled through newspaper articles and bill inserts. Greeley is converting to meters at the rate of 500 meters per year. There is alao a voluntary meter installation program fueled by probable dollar savings to the homeowner. Currently, Greeley is 53% metered. Rates for flat rate customers are based on the number of finished rooms and street frontage. Metered rates have a declining block structure. Table 4.3 shows Greeley's water rate structure for in-city and out of city residents.

TABLE 4.3
WATER RATE STRUCTURE FOR GREELEY

Gallons Per Quarter	Cost Per 1000 Gallons In City	Out of City
Up to 30000	$1.04	$2.08
30000 to 150000	$0.86	$1.72
Upwards of 150000	$0.71	$1.42

Although its programs are sophisticated, the real sting is taken out of Greeley's conservation program by relatively inexpensive water.

Boulder

The city of Boulder has a non-aggressive water conservation program. Although city code allows for mandatory restrictions, no restrictions are enforced or aggressively encouraged. Public education is minimal with only a once per year billing insert encouraging water conservation. The city is 100% metered. All customers are charged a flat fee of $1.95 per month plus a use fee of $0.77 ptg for in-city customers and $0.96 ptg for out of city customers. The city has an ample water supply and has not needed to implement aggressive conservation programs.

Ft. Collins

Fort Collins has a well planned program but lacks the financial incentive caused by metered rates. The city is only 2% metered. Watering restrictions mandate that no watering be done between midnight and 4am exept for sprinklers with automatic controls. This is intended to prevent water from being left on all night. City ordinance prohibits waste when sprinkling and requires that a sprinkler attachment be used on the hose while watering. Customers are required to repair leaks in sprinkler systems and water saving plumbing fixtures are required on all new and replacement construction. The city makes flow restrictors available free of charge at its main office.

Public education is extensive. "Captain Hydro" and "Professor ET" have been and will be part of the fourth grade curriculum at public schools. A one-third acre Xeriscape garden is being completed at the City Hall and ET rates are published in the daily paper and broadcast on radio. Additionally, advertisements to conserve are on public benches and busses.

The few customers on metered accounts pay $9.76 for the first 2000 gallons plus $0.81 ptg for in-city homes or $14.64 for the first 2000 gallons plus $1.22 ptg for out-of-city homes. The bulk of Fort Collins customers pay a flat fee based on total square footage of lot.

Many of the cities add sewer charges to the water bill and base that charge on water use. Whereas this may seem to cause the consumer to use less water, especially in the summer, these billing calculations are based on winter use and would probably not effect summer use patterns. For that reason they are not listed here.

Hypothetical Water Bill

To more easily compare the difference in the financial considerations among cities' programs, a typical bill can be calculated for a "typical" home in each city. As an example, a four bedroom, two bathroom home is used. The home, located within city limits, is on an 8000 square foot lot with 100 feet of frontage. Use for a summer month will be taken as 26,000 gallons. Table 4.4 shows the resulting water bill for each city. Dollar amounts are for water service only and do not reflect sewer or flood control charges.

TABLE 4.4
COMPARISON OF HYPOTHETICAL WATER BILL

City	Metered Monthly Bill	Un-Metered Monthly Bill
Aurora	$35.54	-----
Greeley	9.02	26.52
Longmont	33.80	24.21
Boulder	21.97	-----
Lafayette	67.80	-----
Ft. Collins	29.20	18.15
Broomfield	44.27	-----

From this comparison and from comparison of the non-financial aspects of conservation, the cities can be loosely associated in three groups. Lafayette and Aurora belong to the aggressive group. Although conservation is achieved in different ways, both cities achieve conservation in ways that dramatically affect lawn owning residents. Aurora accomplishes this through its permitting system that limits lawn size. In a city where many new homes are being built, this is a very good program. Lafayette's theory is quite opposite yet affects customers just as much. Its pricing method doesn't directly promote conservation consciousness but it does reduce water use.

Broomfield and Longmont fit best into a moderate group. Broomfield's water prices are fairly high but the city does lack an aggressive public education or community awareness program. Metering of 100% of the homes allows for a more rigorous conservation program but equal rates at all volumes used does not promote conservation. While Longmont is only 39% metered and has less expensive water than Broomfield, it is becoming more consevation minded. A commitment to 100% metering (albeit slow) and an aggressive public education program stimulates community awareness and leads to reducing water use.

Greeley, Ft. Collins and Boulder all fit in the passive group. Ft. Collins has a very structured program in the community. Public and civic education programs are stressed. The lack of metering fails to provide the financial incentive often needed to reduce water use. Greeley, like Ft. Collins, has a very structured plan for public education, restrictions and conversion to metering. Its low price for water necessarily puts it in the passive group. With prices this low, money saved by conserving water is almost inconsequential and the incentive to let the lawn turn brown for the sake of conservation is nonexistant. Boulder is weak in both areas. Water prices are barely higher than Ft. Collins and Greeley and the lack of any serious public education keeps water conservation far from the consumer's mind.

CHAPTER V

RESULTS

Ratings for Each City

The results of the survey are presented in this chapter. Figures 5.1 and 5.2 show relative frequency histograms for each of the seven cities and for the entire sample. Common to each distribution is the skew to the left with the majority of ratings coming in the six to eight range. Scores of zero were more common than scores of ten and the score of seven was the most common. Fort Collins, which tied for the lowest maximum score, had the highest minimum score. In contrast, Greeley had the highest score of all cities surveyed and tied with Aurora for the lowest. One third of Greeley's lawns had a score of nine or better and one half had a score of eight or better. Table 5.1 shows each city's mean quality rating and its rank. The ranks, with a rank of one being the best, are used in later comparisons. The table also shows average range size for the lawns in that city and average appearance rating.

Observation of Figure 5.1 shows that a normal

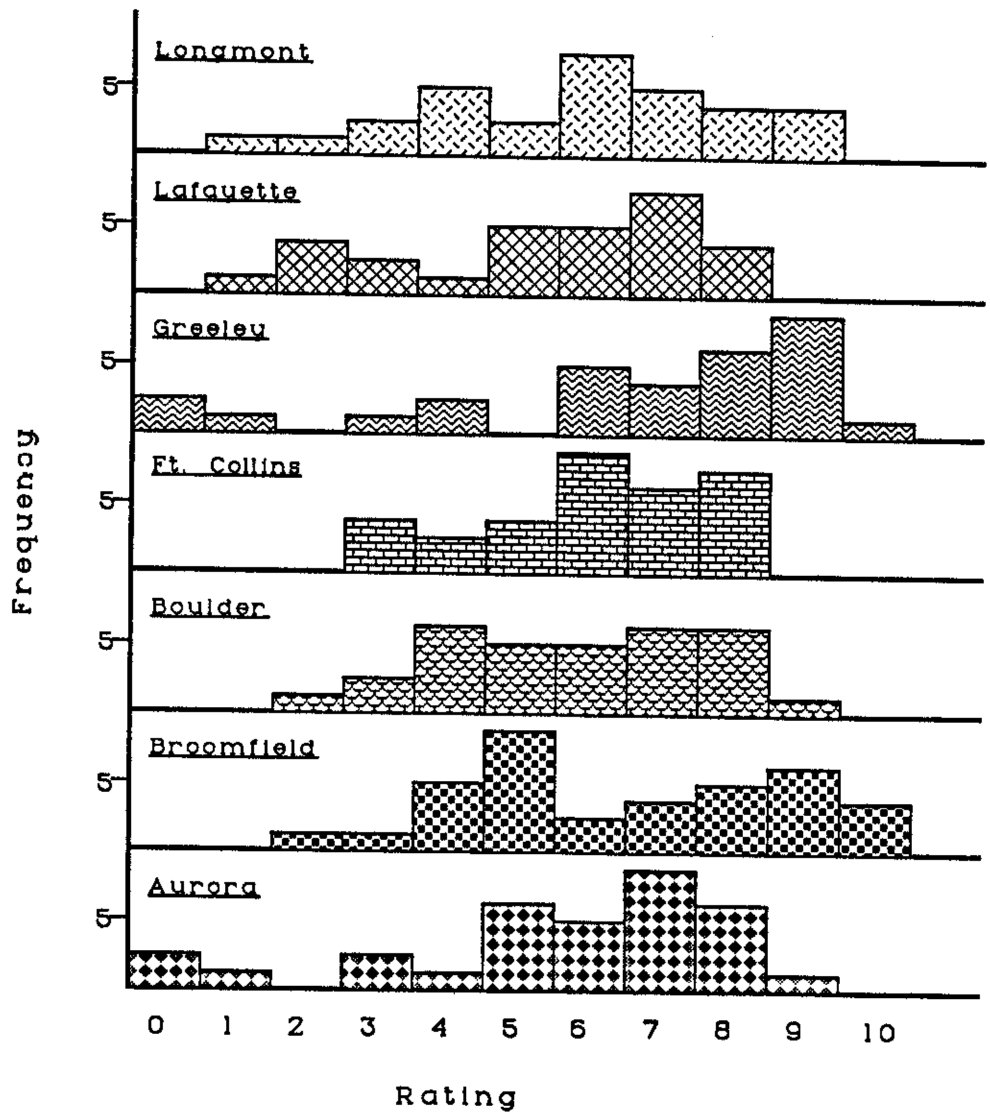

FIGURE 5.1 Frequency histogram of lawn ratings for each city.

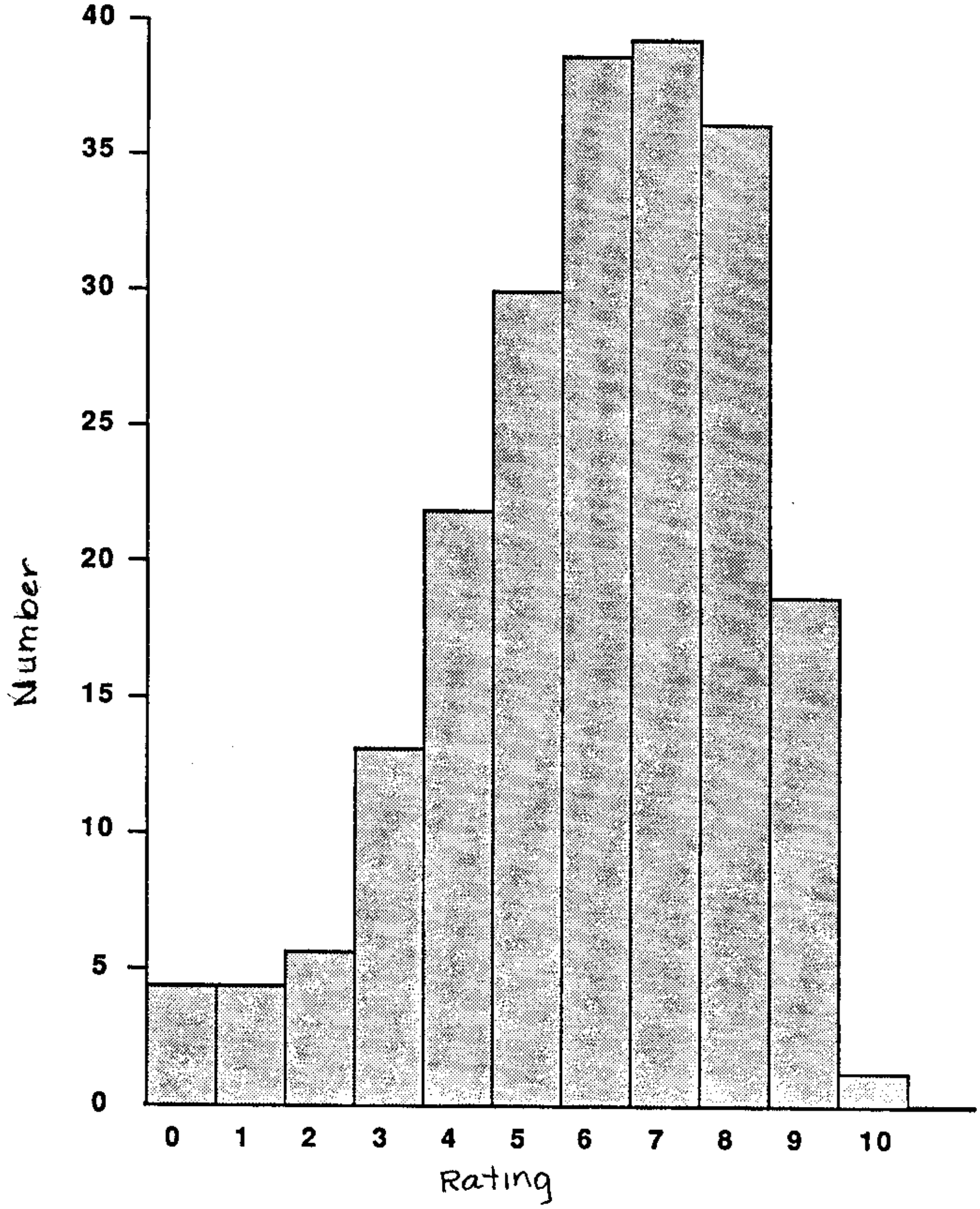

FIGURE 5.2 Frequency histogram of lawn ratings for all 209 lawns.

population distribution is not likely. Because of this, nonparametric statistical methods are employed in the data analysis. The Kruskal-Wallis test was used to test the hypothesis that there is no difference in the quality of lawns against the alternative that a difference does exist. It should be noted here that a hypothesis can be proven false but not true. In the case where the hypothesis is proven false the alternative is accepted. In the case where the hypothesis is not proven false, the hypothesis is accepted as true since no evidence to the contrary exists. In this survey, the hypothesis, that the mean ratings from each city were equal, was not rejected. The interpretation from this test is that, since no evidence exists to the contrary, there is no reason to believe that the cities' lawns differed in quality.

Since Table 5.1 shows that variations up to 15% exist, further tests were run to compare means two at a time. This test compares each city's mean rating with every other city's mean rating. The multiple comparisons test outlined in Noether (1976, p.179) was used. Results from this test showed that Greeley's lawns were of significantly higher quality than the others and that none of the others were statistically different. Yet, differences of up to eight percent exist.

TABLE 5.1
SUMMARY OF SURVEY RESULTS

CITY	LAWN QUALITY RANK	MEAN LAWN QUALITY	MEAN RANGE WIDTH	MEAN APPEARANCE RATING*
GREELEY	1	6.77	2.09	3.38
FT. COLLINS	2	6.13	3.70	3.58
BROOMFIELD	3	5.89	3.70	3.53
LONGMONT	4	5.85	4.17	3.17
BOULDER	5	5.76	5.16	3.19
AURORA	6	5.63	4.07	3.45
LAFAYETTE	7	5.34	4.32	3.29

* scale 1 to 5 (best)

When the cities were grouped according to their water conservation programs (see Chapter 4) The Kruskal-Wallis test yielded interesting results. The test shows that no difference could be found between lawn quality of the passive and moderate groups. The aggresive group, however, had lawns that ranked lower in overall quality. Table 5.2 shows the cities arranged by conservation group and their rank.

TABLE 5.2
RANK ACCORDING TO CONSERVATION GROUP

	CITY	LAWN QUALITY RANK
PASSIVE GROUP	GREELEY	1
	FT. COLLINS	2
	BOULDER	5
MODERATE GROUP	BROOMFIELD	3
	LONGMONT	4
AGGRESSIVE GROUP	AURORA	6
	LAFAYETTE	7

Lawn Quality vs. Water Cost

Table 5.3 shows a comparison of lawn quality rank and low water cost. The water cost is based on the hypothetical water bill developed in Chapter III. The city with the lowest water cost was ranked number one. As the table suggests, there is a strong correlation (correlation coefficient of 0.75) between less expensive water and high lawn quality.

Landscape Appearance vs. Lawn Quality

A Spearman rank correlation test was used to compare overall landscape appearance and lawn quality. In each city a strong correlation was found between

TABLE 5.3
COMPARISON OF LAWN QUALITY
AND LOW WATER PRICE

CITY	LAWN QUALITY RANK	WATER CHEAPNESS RANK
GREELEY	1	1
FT. COLLINS	2	2
BROOMFIELD	3	6
LONGMONT	4	4
BOULDER	5	3
AURORA	6	5
LAFAYETTE	7	7

these two factors. Table 5.4 shows the cities and the correlation coefficient.

TABLE 5.4
CORRELATION COEFFICIENTS BETWEEN
LAWN QUALITY AND YARD APPEARANCE

CITY	COEFFICIENT
GREELEY	0.648
FT. COLLINS	0.640
BROOMFIELD	0.683
LONGMONT	0.683
BOULDER	0.753
AURORA	0.673
LAFAYETTE	0.685

Coefficients can range from -1.0 for perfect negative correlation to 0.0 for no correlation to 1.0 for perfect positive correlation.

Range in Quality vs. Lawn Quality

The same test was used to compare the lawn quality and the range in quality of each lawn. Table 5.5 lists the correlation coefficients of this test by city. No systematic relationship could be found between range size and lawn quality or conservation effort. The three highest correlation coefficients are from cities surveyed by one team, whereas the fourth, sixth, and seventh highest coefficients are from cities surveyed by the other team. Boulder, the city surveyed by one member from each team, had a low correlation coefficient.

TABLE 5.5
CORRELATION COEFFICIENTS BETWEEN LAWN QUALITY AND RANGE SIZE

CITY	COEFFICIENT
GREELEY	0.694
FT. COLLINS	0.516
BROOMFIELD	0.384
LONGMONT	0.973
BOULDER	0.157
AURORA	-0.169
LAFAYETTE	0.138

1985 vs.1986

A final test using the Wilcoxen two sample method (Walpole and Myers, 1985) compared the results of this survey with those of a similar survey done in 1985. The 1985 test was done about a month later in the summer and only ten lawns from each city were rated. The person who did the survey was not a part of either of the 1986 teams.

The test shows that in six of the seven cities there is no reason to conclude that average lawn quality was different from 1985 to 1986. In the seventh city, Lafayette, The average lawn quality was substantially lower in 1986. Table 5.6 lists the cities and their average ratings from 1985 and 1986.

TABLE 5.6
COMPARISON OF
1985 AND 1986 RATINGS

CITY	1986 AVERAGE RATING	1985 AVERAGE RATING
GREELEY	6.77	6.90
FT. COLLINS	6.13	6.60
BROOMFIELD	5.89	6.60
LONGMONT	5.85	7.50
BOULDER	5.76	5.70
AURORA	5.63	**
LAFAYETTE	5.34	7.70

** Aurora was not included in the 1985 survey

CHAPTER VI

CONCLUSIONS

Several tests were done using nonparametric statistical methods which reveal tendencies and trends. Statistical methods should not be interpreted as the "bottom line," especially in a survey that requires a degree of human judgement. Statistical methods do, however, point out trends that probably occur in the population surveyed. The combination of these test results and proper understanding of the mechanics of water consumers and water conservation leads to the following conclusions.

Lawn Quality Comparisons

The results of the first Kruskal-Wallis test infer that no city's average lawn quality was significantly different than that of any other city. However, it is more likely that this test was not sensitive enough, given the amount of data available, to measure the differences in the quality of lawns.

The difference in quality of 15 percent between Greeley and Lafayette, shown in Table 5.1, supports this conclusion.

When individual comparison tests were done, allowing for a greater sensitivity, it was shown that the average quality of Greeley's lawns was significantly different (better) than any of the other cities. Yet, the difference of eight percent between Ft. Collins and Lafayette was not detected by the test.

Greeley's lawns were ranked higher than the others when analyzed by this test. The reasons for this are not defined. Most noticeable about Greeley's conservation program is its low cost for water. Water in Greeley is less than half the cost of any of the other cities for a typical summer month. In contrast to the administrative measures taken by Greeley to enforce restrictions and convert to system-wide metering, the price of water is probably too low to make consumers "think twice" about using excessive water. This lack of financial deterrence probably accounts for the greener lawns in Greeley.

As shown in Table 5.3, there is a strong correlation between low cost of water and high lawn quality. Cost is probably the single most effective factor in curtailing summer outdoor water use. Earlier studies have shown (Chapter II) that moderate price increases are only temporarily successful in limiting water use. Lafayette lawn owners show, however, that very high prices result in substantial conservation, especially in the high volume, summer watering months. It is not suprising that in Lafayette, where water is more than seven times as expensive as Greeley, lawns are ranked last in quality. What is suprising is that the difference in quality isn't greater.

Comparisons of Rank

The remainder of the tests involved ranking the cities according to their average lawn quality and comparing these rankings. It should be noted here that the ranks assigned are arbitrary numbers. For example, the difference in quality between cities ranked one and two is not necessarily equal to the difference between cities ranked four and five. The cities were grouped into three catagories as discussed in Chapter III. The cities with aggressive programs ranked poorer in quality than the rest of the cities. Actually, taking into consideration the test's insensitivity to small differences, the difference between passive and moderate groups is less than that between moderate and aggressive groups.

In Lafayette's case this is explainable by the high water prices. Aurora, however, has moderate prices and a good community education program. It is suspected that the Aurora lawns were ranked low due to systematic error. Approximately one half of the homes surveyed in Aurora were less than three years old. The cause for poor overall quality may be due to immature lawns rather than underwatered or under-cared-for lawns.

Very noticable in the passive group is the presence of the fifth ranked city, Boulder. Boulder's lawns were ranked fifth in quality yet its conservation policy is among the least stringent. Water prices are low and no restrictions are enforced or even promoted. One factor might be the suspected higher rental rate in Boulder, although no data on this were taken. Recalling Hoag's conclusions (see Chapter II), it is probable that the lack of a good community education program is also responsible. Tips for good maintanance habits meant to conserve water may actually promote better looking lawns through good plant health.

In order to assess maintanance habits, landscape appearance was also rated. The survey found a strong correlation between good yard appearance and high lawn quality. It appears that good lawns are the result of careful and regular maintanance (including watering) rather than only heavy application of water.

The varying micro-climates of the lawn are probably most responsible for the uniformity in lawn quality. As suggested in Chapter V, the varying degrees of correlation between range size and lawn quality are probably the result of experimental error. Good correlation in lawns surveyed by one team and little or no correlation in lawns surveyed by the other team indicate that methods of assessing range size were not consistant. The best "control" sample, Boulder, showed very little correlation. One might think that higher quality lawns would tend to have less variation, but there is no evidence to support this.

1985 vs. 1986

A final test was done to compare data taken in the summer of 1986 with that taken the previous summer. The 1985 data was taken in the same manner but by a different person. In six of the seven cities the test concludes that average quality did not change. In Lafayette, however, the quality changed more than 23%. This variation is too large to assume that none of the other quality ratings changed. Rather, it is likely that the statistical test used was insensitive to smaller changes. Table 6.1 justifies this conclusion. Longmont's average quality decreased over 16% yet this went undetected by the test used. This is a good example of the difficulty of working with data following a nonnormal distribution.

TABLE 6.1
PERCENT CHANGE IN QUALITY RATING FROM 1985 TO 1986

CITY	% CHANGE
GREELEY	- 1.3
FT. COLLINS	- 4.7
BROOMFIELD	- 7.1
LONGMONT	-16.5
BOULDER	+ 0.6
AURORA	----
LAFAYETTE	-23.6

Table 6.1 shows that quality ratings were lower in 1986 than in 1985. Since the ten homes surveyed in 1985 were also surveyed in 1986, there are two possible explanations. One is that lawns actually were lower in quality due to less maintanance or

applied water. But, since weather conditions were very similar and conservation measures were consistant over the two years, there is no supporting evidence for this. The more likely explanation is that the observation practices were different during the two years. Chances are that the variance was due to the judgement of the surveyors and the smaller sample size in 1985, rather than a real drop in lawn quality.

Further Testing

There is a need for further study in this area. Controlled experiments isolating the various aspects of water conservation policy (restrictions, price, public education, etc.) could be done to determine quantitatively the role of each. The results of such a test would be very helpful to municipalities in determining the most cost effective way of achieving conservation. These tests would have to be done on actual lawns since the human factor is such a large element in the results.

A more consistant and encompassing way of measuring quality should be developed. Such a method could, for example, include stand thickness, percentage of barren area, weed presence and percentage of greenness. A quantitative way to tally the results is necessary for the statistical analysis, but is elusive.

Summary

With limited water supply and increasing population, conservation is fast becoming an important factor in city planning. More than 50% of the treated water in Colorado goes to outdoor use, primarily to urban lawns. Thus, the biggest focus of conservation has been on limiting the application of water to residential lawns.

In response to the concern for the maintained quality of urban lawns, a random survey of 209 lawns in seven Colorado Front Range cities was taken during the summers of 1985 and 1986. The purpose was to determine whether the various conservation programs in the different cities caused a difference in the quality of lawns. The results could benefit cities by helping them to develop conservation programs which minimize the effect on quality of residential lawns. Through this, the cities could find the support they need in achieving conservation goals set to forgo costly supply development.

The results of the survey were analyzed statistically, but the tests used were not always sensitive enough. It was found that the difference in the quality of lawns in the various cities due to conservation measures is small (less than 15%) but does exist. Moreover, it was suggested that rigorous public education programs were helpful in promoting good maintanance habits. Ultimately it was found that high water prices and poor maintanance habits were responsible for poorer quality lawns. A combination of moderate to low prices and the promotion of good maintanance through public education led to good lawn quality.

The literature shows that water is probably over applied to lawns in most communities and that water conservation can be achieved when the public is well informed and convinced that conservation is in their best interests. This project shows that there is a small difference in the quality of lawns of cities with aggressive, moderate or passive conservation programs. Further testing could be done in determining the effects of specific aspects of water conservation.

BIBLIOGRAPHY

Aurasteh, M.R. (1983), A Model for Estimating Lawn Grass Water Requirements Considering Deficit Irrigation, Shading and Application Efficiency, Unpublished Doctoral Dissertation, Utah State University, Logan, Utah.

Baumann, D. (1986), "Consumer Adoption of Water Conservation: Effectiveness of Public Information", Presented at the AWWA Annual Conference, June 24, 1986, Denver, Colorado.

Bollman, F.H., Merritt, M.A. (1977), "Community Response and Change in Residential Water Use to Conservation and Rationing Measures: A Case Study - Marin Municipal Water District", California Department of Water Resources, Sacramento, California.

Bruvold, W.H. (1978), "Consumer Response to Urban Drought in Central California", School of Public Health, University of California, Berkeley, California.

Cotter, D.J., Croft, D.B. (1974), Water Application Practices and Landscape Attributes Associated with Residential Water Consumption, New Mexico Water Resources Institute, Report No. 49, Las Cruces, New Mexico.

Danielson, R.E., Hart, W.E., Feldhake, C.M., Haw, P.M. (1979), Water Requirements for Urban Lawns, Office of Water Resource and Technology, U.S. Department of the Interior, Washington D.C.

Danielson, R.E., Feldhake, C.M., Hart, W.E. (1981), Urban Lawn Irrigation and Management Practices for Water Saving with Minimum Effect on Lawn Quality, Colorado Water Resources Research Institute, Completion Report No. 106, Ft. Collins, Colorado.

DiNatale, K.N. (1980), An Assessment of Water Use and Policies in Northern Colorado Cities, Unpublished Master's Thesis, University of Colorado, Boulder, Colorado.

Ellinghouse, C., McCoy G. (1982), The Effects of Water Conservation on New Water Supply for Urban Colorado Utilities, Colorado Water Resources Research Institute, Completion Report No. 120, Ft. Collins, Colorado.

Flack, J.E. (1981), "Residential Water Conservation", Journal of the Water Resources Planning Management Division, American Society of Civil Engineers, p.85.

Flack, J.E. (1982), Urban Water Conservation, American Society of Civil Engineers, New York, New York.

Flemming, R.R. (1964), "When and How to Use Water Meters", The American City, V 79, N 6, pp. 110-112.

Greenberg, J.J. (1981), Public Receptivity toward Water Conservation in Northern Colorado Communities, Unpublished Master's Thesis, University of Colorado, Boulder, Colorado.

Hanke, S.H. (1969), The Demand for Water Under Dynamic Conditions: A Case Study of Boulder, Colorado, Unpublished Doctoral Dissertation, University of Colorado, Boulder, Colorado.

Hanke, S.H., Mehrez, A. (1979), "The Relationship between Water Use Restrictions and Water Use", Water and Supply Management, V 3, Pergamom Press Ltd., Great Britain, pp. 315-321.

Hoag, L.N., Yost, J.A., Maddaus, W.O. (1981), Water Conservation Management, American Water Works Association, Denver, Colorado.

Howe, C.W., Linaweaver, F.P., Jr. (1967), "the Impact of Price on Residential Water Demand and Its Relation to System Design and Price Structure", Water Resources Research, V 3,N 1, p. 13.

Kneebone, W.R., Pepper, I.L. (1979), Water Requirements for Urban Lawns, Office of Water Research and Technology, U.S. Department of the Interior, Washington D.C.

Linaweaver, F.P., Jr., Geyer, J.C., Wolff, J.B. (1967), A Study of Residential Water Use, Johns Hopkins University, Baltimore, Maryland.

Maddaus, W.O. (1986),"Finally, Some Hard Data on Water Conservation", Presented at the AWWA Annual Conference, June 24, 1986, Denver, Colorado.

Martin, W.E., Ingram, H.M., Laney, N.K., Griffin, A.H. (1984),Saving Water in a Desert City, Resources for the Future, Inc., Washington D.C.

Nelson, J.O. (1976),North Marin County's Little Compendium of Water Saving Ideas, North Marin County Water District, Novato, California.

Nelson, J.O. (1986),"Water Conserving Landscapes Show Impressive Savings", Presented at the AWWA Annual Conference, June 24, 1986, Denver, Colorado.

Noether, G.E. (1976),Introduction to Statistics, Houghton Mifflin Co., Boston, Massachusetts.

Pochop, L.O., Borrelli, J. (1979),Water Requirements for Urban Lawns, Office of Water Research and Technology U.S. Department of the Interior, Washington D.C.

Rondon, J. (1980),Landscaping for Water Conservation in a Semiarid Environment, Department of Utilities, City of Aurora, Colorado.

Russell, C., Arey, D., Kates, R. (1970),Drought and Water Supply, Johns Hopkins Press, Baltimore, Maryland.

Uno, G. (1974),Be Water Wise, Water Conservation: Its up to You, Prepared for the Denver Water Department.

Walpole, R.E., Myers, R.H. (1985),Probability and Statistics for Engineers and Scientists, MacMillan Publishing Co., New York, New York.

Weakley, W.P. (1977),Residential Water Conservation, Unpublished Master's Thesis, University of Colorado, Boulder, Colorado.

Williamson (1975),Statistics of Water Use, Water Research Foundation of Austrailia, Nedlands, Austrailia.