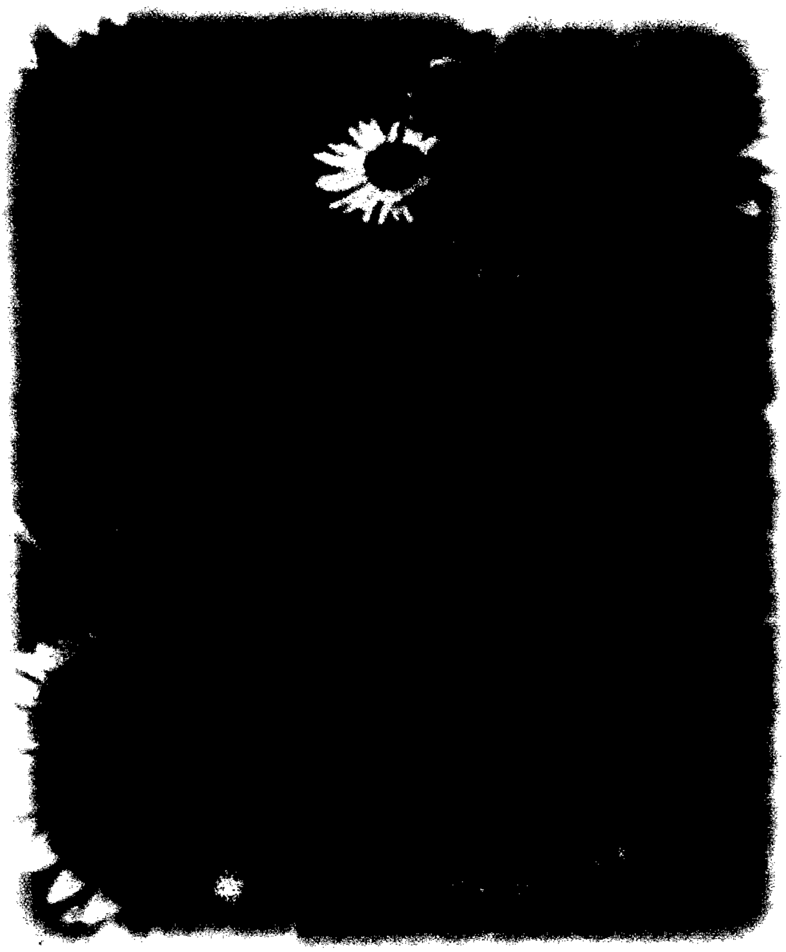
XERISCAPING:

Promises and Pitfalls



Report for Texas Water Development Board

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XERISCAPING:

Promises and Pitfalls

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Xeriscaping: Promises and Pitfalls

A Multivariate Research Study of Xeriscape Practices, Water Consumption, and Water Quality

Executive Summary

The City of Austin conducted a comparison study of residential water consumption in 1992-1993 to determine the water savings potential of xeriscape. The *Residential Xeriscape Project* was supported by a matching grant from the Texas Water Development Board. This evaluation report should prove valuable in the City's effort to achieve a 10% reduction water consumption by the year 2000.

Analysis of data during the first phase of the *Residential Xeriscape Project* suggested an average water savings of 16% to 40% percent through xeriscaping. The research objectives of the second phase were to:

- Confirm the average water savings associated with xeriscape.
- Explore other landscape and social-economic factors that constrain or increase the water savings.
- Explore the possible association of xeriscape with higher water quality.

Methodology

The research approach was both confirmatory and exploratory with the statistical analysis guided by a predictor-outcome framework. Predictors are the factors hypothesized as influencing the outcomes of summer (outdoor) water consumption and outdoor chemical use. The predictors included winter (indoor) water consumption, lot size, house value, geographic area, irrigation method and grass type. Types of grass were St. Augustine, Bermuda, mixed grass (a combination of St. Augustine and Bermuda), no grass (all shrubs or ground covers), and Buffalograss. The selection of predictors was motivated by evidence found in available research publications, communications with other professionals conducting conservation research, and discussions with City of Austin Environmental and Conservation Services Department staff.

Multivariate statistical analysis identified the best set of predictors which accounted for the most variation among outcomes and determined the magnitude of each predictor-outcome relationship while removing the influences from other predictor-outcome relationships. Simple group comparisons were also used to describe differences in water consumption associated with the predictors, as well as to show how such results can be misleading without using multiple regression analysis to disentangle overlapping predictor effects.

Two samples were collected: the *landscape sample* and the *questionnaire sample*. In the *landscape sample*, the study team used a cluster sampling approach with 42 clusters and collected information about the landscape characteristics through an observational drive-by procedure for all sites in a cluster. A total of 7,110 residential sites were examined.

In the *questionnaire sample*, a questionnaire was mailed to a subsample of the residences in the landscape sample. The questionnaire was mailed to *all* the residential sites classified as xeriscapes and a randomly selected comparison group. The questionnaire inquired about chemical use (the outcome related to water quality) as well as additional predictors such as money and time spent on landscaping.

Results

The difference in water consumption between a xeriscape with no grass or Buffalograss as compared to traditional St. Augustine grass landscapes averages 31 percent, about 175 gallons per day (gpd). This confirmatory estimate is within the bounds of the expected water consumption savings based on previous research. The absolute reduction in water consumption appears to be constant over lot sizes and house values, therefore the greatest opportunity for percentage savings will be in lower and middle house value areas without irrigation systems.

Approximately 40 percent of the *total variation* in summer water consumption can be accounted for or explained with four predictors: 1) winter water consumption, 2) house value, 3) irrigation method, and 4) type of grass. The type of grass and irrigation method each accounted for 10 percent of the *explained variability* in summer water consumption; house value (geographic area or neighborhood affluence) and indoor water consumption each accounted for 40 percent.

Other key findings are:

- Bermuda grass is associated with a 14 percent (81 gpd) reduction in water consumption as compared to St. Augustine grass.
- Irrigation systems are associated with approximately a 38 percent (214 gpd) increase in water consumption.
- After controlling for other factors, the highest income areas are associated with a 57 percent (324 gpd) increase in water consumption as compared to the mid-range income areas; conversely, the lowest income areas are associated with a 28 percent (161 gpd) decrease in water consumption.
- Money and time spent for landscaping tend to increase water consumption.
- St. Augustine grass landscapes more frequently use chemical fertilizers.

Implications and Recommendations

The promises and potential pitfalls in the development of xeriscape promotion programs are presented with a social behavioral model to guide future research and program refinement. The model depicts six key service components of a xeriscape program (promotion, education, purchase incentives, goal setting, monitoring and feedback, and performance rewards) influencing customer perceptions and decision making. A preliminary cost-effectiveness analysis of the xeriscape rebate program is also presented to clarify two important assumptions that need to be included in calculating long term return on investment: free ridership and a social diffusion multiplier. The cost analysis shows that xeriscape rebates are a cost effective demand side management tool if the free ridership is low and the diffusion multiplier is positive. Finally, the future development of xeriscape promotion should be a sequence of program start up, implementation evaluation and program refinement, and the establishment of ongoing cycles of continuous quality improvement.

Introduction

Since 1985, the Environmental and Conservation Services Department (ECSD) of the City of Austin has promoted the use of xeriscaping principles to reduce peak day water consumption during the summer months. ECSD currently has an extensive xeriscape public education program including distributing xeriscape literature, developing xeriscape demonstration sites, and offering rebate incentives to homeowners and builders to install xeriscape grass areas and plant beds.

In 1991, ECSD initiated a program of research on xeriscaping and water conservation. The *Residential Xeriscape Project: Phase I Study* revealed an average 40 percent (123 gpd) reduction in water consumption in xeriscaped residential sites with lot sizes less than 9,000 square feet. For sites with lot sizes greater than 9,000 square feet, the results were not conclusive. Based on the results of the Phase I study, xeriscaping offered significant promise as a strategy for water conservation by working with lot sizes below 9,000 square feet. An additional examination of the Phase I data that adjusted for sampling bias revealed a 67 gpd (16%) reduction in water use in xeriscapes for all lot sizes (Sokulsky, 1993).

Purpose of the Residential Xeriscape Project: Phase II

The Phase II study included three objectives:

- Confirm the water savings associated with xeriscaping.
- Explore other factors that constrain or increase the water savings to be realized through xeriscaping.
- Explore the possible association of xeriscaping with higher water quality by reducing outdoor chemical use and runoff.

To accomplish these objectives, the Phase II study examined separately the components of xeriscaping, employed a large sample size, and implemented a representative study participant selection procedure. Also, more powerful techniques of statistical analysis were applied. Data relating to outdoor chemical use was collected and analyzed to address the relationship between xeriscaping and water quality.

Definition of Xeriscaping

The official definition of xeriscaping, as advocated by the National Xeriscape Council, (1991) includes seven principles: 1) the use of drought resistant grasses and plants, 2) reduced or limited turf, 3) grasses and plants matched appropriately to soil composition, 4) use of mulches, 5) efficient irrigation, 6) planning and design, and 7) proper maintenance practices. In the Phase II study, the primary defining feature of xeriscaping is *the use of drought resistant grasses and plants.*

For the climate and soil in the Austin area, xeriscape grasses include 'Prairie' Buffalograss, '609' Buffalograss, Bermuda, and no-grass landscapes. No grass landscapes are entirely xeriscape shrub and ground cover areas. Mixed grass (Bermuda with St. Augustine) has greater drought tolerance than St. Augustine grass alone. For this reason mixed grass is examined separately from St. Augustine. (See Figures 1 and 2.)

Figure 1. Buffalograss in the Austin geographical area.

Figure 2. No grass xeriscape in the Austin geographical area.

Recent Research on Xeriscape

To determine if xeriscaping is associated with lower water consumption, four studies have recently been completed. The studies show on average a 20 to 40 percent reduction in water consumption in xeriscaped residential sites (see Table 1).

The Mesa study, the East Bay MUD study, and the City of Austin Phase I study on xeriscaping used group comparisons to develop causal inferences. Single group comparisons cannot reveal the multiple influences on water consumption that may exist. It is possible that xeriscaped lawns tend to be associated with other factors. If this is so, then the water efficiency allegedly resulting from xeriscaping could in fact be caused by the differences in other factors such as irrigation method or income level (house value). To disentangle the influences from other factors associated with landscape choice, the City of Austin Phase II study used multivariate statistical techniques.

Generalizing the findings of these studies conducted in Arizona and California to the Austin area can be questioned even further because of differences in climate and the definition of xeriscape used. In the other xeriscape studies, the definition of xeriscape requires reduced turf area. In the City of Austin's Phase II study, the definition of xeriscape allows for large turf areas if drought tolerant grasses are used.

Mesa, Arizona (Testa and Newton , 1993)

- Xeriscaping in Mesa is the use of desert plant materials.
- Xeriscaping is associated with a 33 percent reduction in water consumption.
- The study examined 138 new landscapes (75 Rebate group and 63 control group).
- Since 1985, a 5 percent per year increase in the fraction of low water use landscapes installed in new homes is attributed partially to the rebate program.
- Community "standards" were found to be social forces that strongly influenced the choice to xeriscape.

East Bay Municipal Utility District, California (Bent, 1992)

- Xeriscaping was found to be associated with an average reduction of 43 percent (209 gpd) in water use — an estimate very similar to that found by the City of Austin, Phase I Study.
- A large sample of 1,040 residential sites was used (520 xeriscapes and 520 traditional landscapes). Matched xeriscape and comparison groups were selected from adjacent residences providing some control for "nuisance" variation in water consumption due to differences in geographic and demographic factors.
- Irrigation systems were associated with a 36 percent *increase* in water consumption. It is quite possible that the alleged xeriscape driven savings in water consumption was caused by a correlation between traditional landscaping and the presence of irrigation systems.

North Marin Study (Nelson, 1994)

- Preliminary results of the North Marin multivariate research study showed that xeriscaping saves between 120 to 207 gpd, about a 25 percent savings on average at the central tendency of the water consumption distribution.
- The North Marin results showed that underground irrigation increases consumption by 162 gpd. Also, the report suggests that winter use, house value, and appearance are important factors in describing water consumption.
- The r-squared value for the regression model was 0.42 in the North Marin multivariate study, thus indicating approximately 40 percent of the variation in water consumption could be predicted.

City of Austin Phase I Adjusted for Sampling Bias (Sokulsky, 1993)

- The predictors that account for significant amounts of variance included income level, weather conditions, number of persons per household, and whether or not the household received the xeriscape newsletter. On this small sample (N≈100), the factors of the price of water, minimum billing charge, and lot size were not statistically significant.

Based on these studies, communications with other professionals conducting conservation research, and discussions with staff, a predictor-outcome framework was chosen to guide the Phase II Xeriscape Study.

Study	**Sampling Method**	**Number of Sites**	**Analysis Method**	**Xeriscape Savings**
Mesa, Arizona	Selected rebate participants and a random control group	150	Univariate	142 gpd 33% difference
East Bay M.U.D., California	Random sample	1040	Univariate	209 gpd (42%)
North Marin Residential, California	Random sample with a questionnaire assessing additional predictors	382	Multivariate	126 to 207 gpd (25%)
City of Austin Phase I: 1992	Units selected from a xeriscape newsletter and a bulk mailing with a 5% response rate	100	Univariate blocking for lot size	40 % savings for small lots (107 gpd)
City of Austin Phase I: 1993 (Adjusted for Bias)	Units selected from a xeriscape newsletter and a bulk mailing with a 5% response rate	100	Multivariate correction of sampling bias	67 gpd (16%)

Table 1. List of major study results on xeriscape impact on water use.

Confirmatory-Exploratory Approach

Predictor-Outcome Framework — A predictor-outcome framework guided the design of data collection and multivariate statistical analysis in the Phase II study.

Predictors are variables which could impact the outcomes of water consumption and outdoor chemical use. The predictor-outcome relationships investigated in this study are shown below in Figure 3. Xeriscaping, lot size, irrigation systems, and six other factors were the primary set of predictors for outdoor water consumption. Winter water consumption, a measure for indoor use, can also be considered a predictor, but it is separated from the others to emphasize that indoor use should be controlled when examining the outdoor water consumption.

Outcomes are variables which represent results or consequences of concern. In this study, the outcomes are water consumption and outdoor landscape chemical use. Outcomes are assumed to be influenced, caused, or moderated by the predictors.

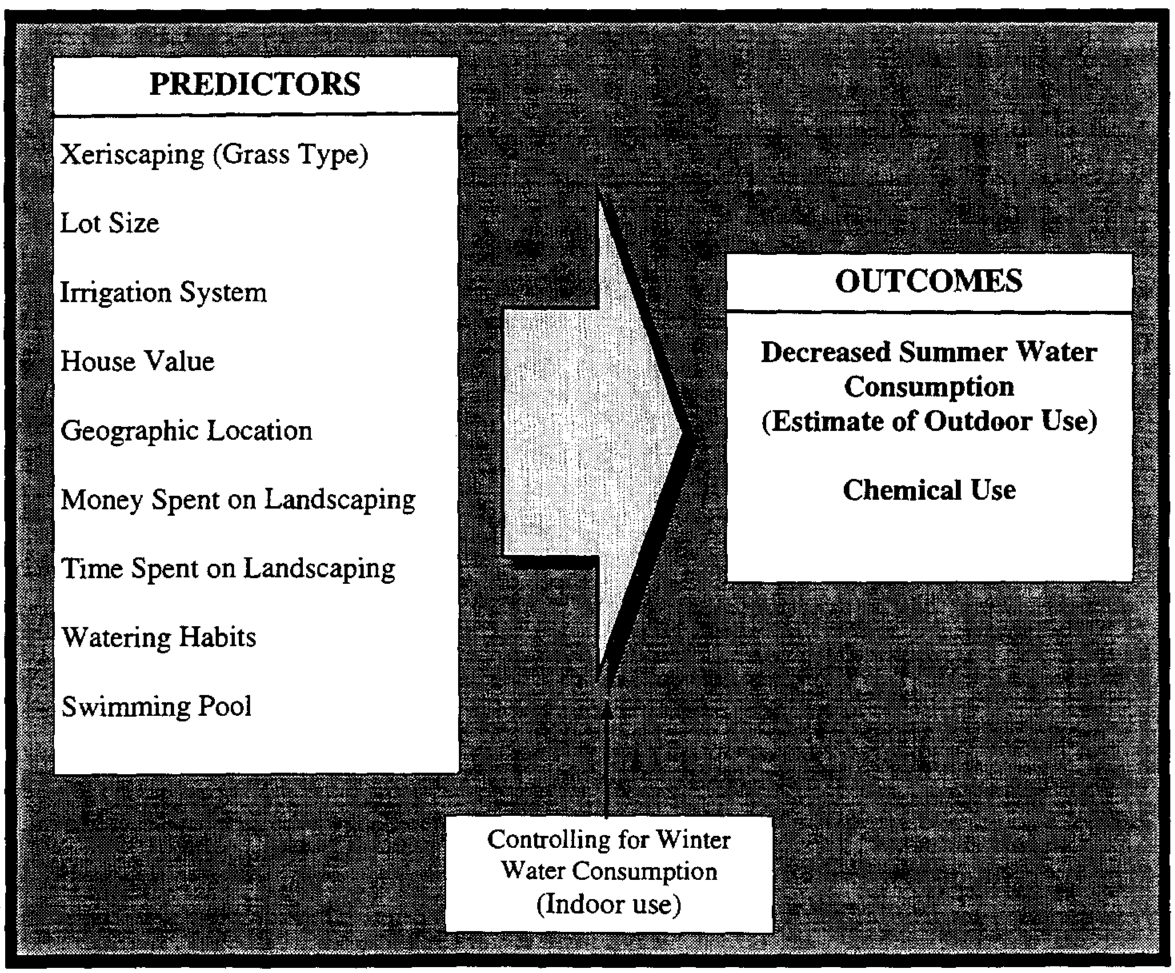

Figure 3. Predictor-Outcome Framework.

Limitations of the Phase II Study

Because the Phase II Study was based on correlational data about current landscapes, the results do not reveal the effects of changing from a traditional landscape to a xeriscape on water and pesticide/fertilizer consumption. The Phase II results identify the predictors associated with outcomes and the estimated magnitudes of such associations. Since the results are based on correlational data, interpretations about *causal* relationships must remain suggestive until demonstrated through randomized experiments.

It is important to keep in mind that there are *unmeasured characteristics* of individuals who participated in the study that might explain why some people choose to xeriscape and conserve water. The design of the Phase II study can not rule out the potential bias of participant self-selection into xeriscape and traditional landscapes groups. Research on the characteristics of people who choose to xeriscape needs to be conducted in the future.

Research Questions

The predictor-outcome framework guided the Phase II data collection and analysis to address the following research questions:

1. *Is there a potential 40 percent savings in water consumption, on average, associated with xeriscape practices?*

2. *Do additional social-economic or landscape factors influence the water savings from xeriscaping?*

3. *Is xeriscaping associated with reduced outdoor chemical use?*

Methodology

Overview of Research Design

The research team selected residential sites by a cluster sampling method. In this study, a cluster is defined as a water meter reading route (about 200 homes in the same geographic location within an approximate three miles or less radius). The study team used both randomly selected clusters and purposely selected clusters, so that the results could be generalized to the entire Austin area.

Landscape architects conducted a visual data collection procedure to observe and code landscape features of the residential sites in each cluster. After codifying the landscape features, data on water consumption and geographic location of the residential sites were extracted from city records. The influences from xeriscaping, geographic location, and other key predictors (such as irrigation systems) were rigorously investigated using 7,110 residential sites. This sample is referred to as the *Landscape Sample.*

To explore the relationship of water consumption and outdoor chemical use with other predictors such as money spent landscaping, the research team mailed a questionnaire to 435 occupants of residences in the landscape sample. All the homes with xeriscape type landscapes (limited turf area, Buffalograss, or no grass) were mailed questionnaires (150 cases). Questionnaires were also mailed to occupants of residences with traditional landscapes and partial xeriscapes using a random selection procedure from the landscape sample. A total of 270 questionnaires were returned (a 62% response rate). A copy of the questionnaire is in Appendix B. This sample is referred to as the *Questionnaire Sample.*

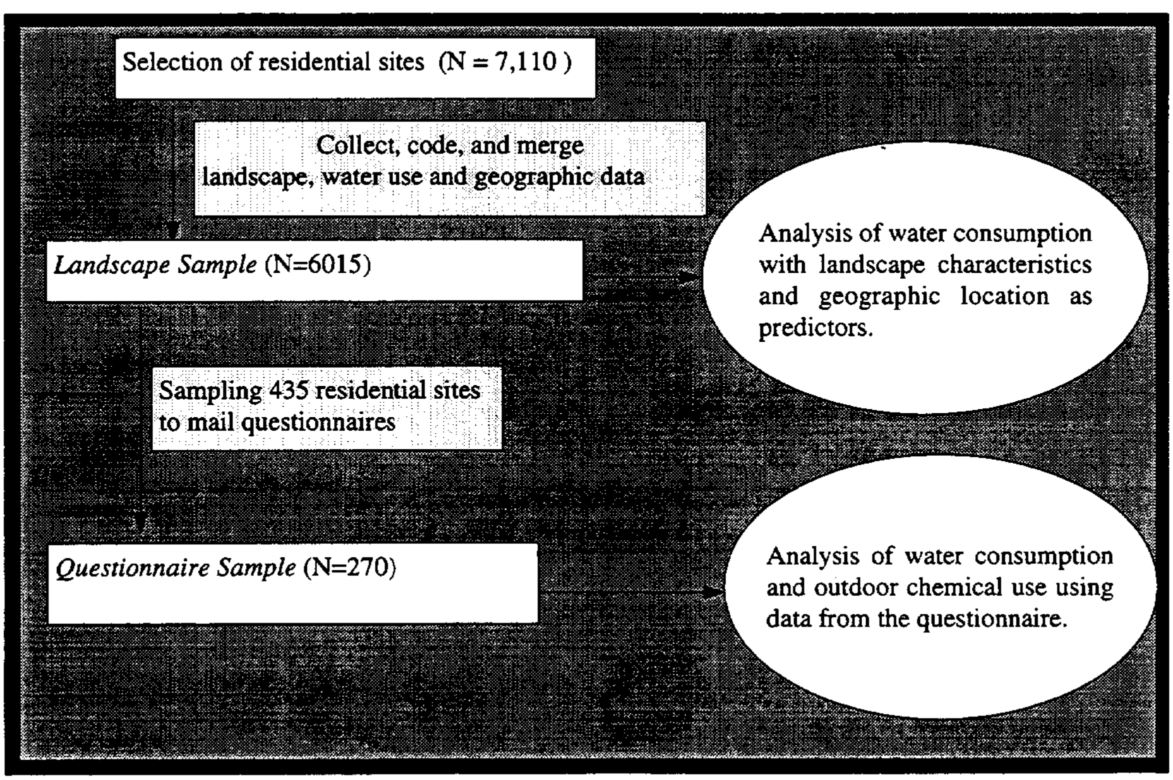

Figure 4. Overview of Research Design

Data Collection

The study team collected information from a drive-by observational procedure, the utility's water consumption database, a questionnaire, and the Travis County Appraisal District tax database. The information from different sources was merged by street number and street name.

Drive by Observational Data

Study team members who are professional landscape architects observed the landscape characteristics (grass type, grass area, plant bed area, and irrigation method) of all homes in the selected clusters in the Fall of 1992.

Water Consumption Data

The information on water consumption from the billing records was merged with the information collected during the drive by observations. Data on the 7,110 sites in the drive by observations was merged by name and address. This resulted in 6,910 sites. About 200 sites were lost due to coding errors. Residents who changed their address in 1992 were removed from the database, resulting in the deletion of about 800 sites. The reason for removing individuals who are new to a water account is to ensure that all homeowners in the study have had time to establish stable water use patterns. If the summer or winter months had unreasonable values for water consumption (less than 1,000 gallons in a month or more than 200,000 gallons in a month), then the sites were deleted from the data set. About 35 sites were removed for being less than 1,000 gallons per month and one site was removed for high consumption. The reason for removing sites with unreasonably low or high water consumption is to control the influence of outlying data points on the regression models. After the deletions, 6,015 sites remained in the data set.

Questionnaire Data

Questionnaires were mailed to selected homes in the large landscape sample to explore the predictors associated with outdoor chemical use and to investigate additional predictors associated with water consumption, . All sites with xeriscaped landscapes (Buffalograss, reduced turf areas, and no grass) were mailed a questionnaire (N=150). Residential sites categorized as partial xeriscape (Bermuda or mixed grass) or traditional landscapes (largely St. Augustine grass) were randomly selected to participate (N=290). The total response rate was 62%.

House Value and Lot Size Data

Information on the house value and lot size were extracted from the Travis County Appraisal District tax database for all sites that returned questionnaires. To extract tax data, each site had to be manually located in the computer record system. This cost of manual data extraction limited the collection of tax records to sites that returned questionnaires. For other sites in the landscape sample, the study team coded the relative affluence of house values based on geographic location. It was assumed that geographic location in Austin provided similar information as tax house value.

Information in the Landscape Sample

The landscape data set (N=6015) contained information from the drive by examination of landscapes and the water consumption billing records.

Outcome in landscape sample

- **Summer Water Consumption:** The sum of the water consumption in July and August extracted from billing records. Because different homes have their meters read on different days of the month, the study team linearly adjusted the billing records to approximately match the calendar date.

Predictors in the landscape sample

1. **Grass Type:** The type of grass in the landscape coded during the drive by observations. The grass types included Bermuda grass, St. Augustine, Buffalograss, mixed (a combination of Bermuda, St. Augustine, and other grasses), and no grass in the landscape. St. Augustine landscapes served as the reference group in examining the difference in water consumption between the grass types.

2. **Grass Area:** The fraction or ratio of the total landscape to turf. The grass area ratio was coded as 0-1/3, 1/3-1/2, and more than 2/3.

3. **Plant Area:** The opposite of grass area, also coded as 0-1/3, 1/3-1/2, and more than 2/3.

4. **Winter Water Consumption:** The estimated amount of wastewater that a customer sent to the sewer system. It is based on the average water consumption in the winter months. Comparison of wastewater treatment records with water pumping records for the winter months indicates approximately 90% of the water pumped returns to the wastewater treatment centers in the winter. Thus, winter water consumption is a good estimate of indoor use during the summer months.

5. **Irrigation System:** A (0/1) indicator of the presence of an underground irrigation system. About 23 percent of homes were coded as having underground irrigation.

6. **Cluster:** One of 42 areas located in the Austin water service region selected to be in our study. Each cluster contained approximately 200 sites within a three mile radius.

7. **Geographic Location**: One of eight groups of residential sites defined by similar house values and locations based on cluster membership. A middle income area in North Austin served as the reference group. Geographic location also contains some information about community standards for landscape maintenance.

8. **Shade:** A (0/1) indicator for the amount of tree cover in the landscape. [Note: this predictor failed to account for a significant variance of the outcome when other predictors were included in the multiple regression analysis.]

Information in the Questionnaire Sample

The questionnaire data set (N=270) contained the information in the landscape data set plus the self-reported information about chemical use and additional predictors, see Appendix B.

Outcomes in the questionnaire sample

- **Summer Water Consumption:** Same as the landscape sample.
- **Chemical Use:** The sum of self-reported chemical use (fertilizer, pesticide, and weed killer applications per year) which represents the total number of chemical applications per year (0-9 scale). The linear sum of the number of chemical applications represents an estimate of the environmental harm. For other outcomes, individual number of applications and type of products used, see Appendix F.

Additional predictors in the questionnaire sample

1. **Xeriscape, Partial Xeriscape, and Traditional Landscape:** A classification based on plant bed area and grass type that was used to mail the questionnaire.
2. **House Value:** The estimated value from the Travis County Appraisal District records. House values less then $40,000 were adjusted to $40,000 and house values greater than $180,000 were adjusted to $180,000. About 15 values were adjusted.
3. **Lot Size:** The lot size from the Travis County Appraisal District records. Lot sizes greater then 13,000 sq.ft. were adjusted to 13,000 sq.ft. About 10 values were adjusted.
4. **Money Spent Landscaping:** The self-reported amount spent landscaping per year in question 12. Values range from a) less than $50 per year, b) $51 to $200 per year, c) $201-$500 per year, d) $501-1000 per year, and e) over $1000 per year.
5. **Time Spent Landscaping:** The self-reported amount of time spent landscaping per month in question 7. Values range from a) 0-4 hours, b) 4-8 hours, c) 8-16 hours, d) 16 to 24 hours, e) more than 24 hours, and f) I do not know.
6. **Self-reported Irrigation System:** The presence of an irrigation system.
7. **Pool:** The presence of a pool (0/1 indicator).
8. **Self-reported Frequency and Duration of Watering:** For an analysis that uses this predictor as an outcome, see Appendix C.
9. **Age and Gender of respondent, Number of Persons per Household, Method of Scheduling Irrigation, Source of Information on Landscape Practices, Money Initially Spent on Landscape, and Lawn Maintenance Information:** were also collected in the questionnaire. [Note: These predictors failed to account for significant variance of the outcomes when the other predictors were included in the multiple regression analysis.]

Characteristics of the Landscape Sample

A clear majority of the observed landscapes contained large grass areas (88 percent of the total sample of sites had two-thirds or more of the area in their landscape as grass). Most turf areas were composed of St. Augustine grass (60%). Approximately one fourth of the sites had underground irrigation systems (23%).

Table 2. Percentages of grass area in the sites.

Grass Area	Number of Sites	Percent of Sites
0	232	3%
0-1/3	197	3
1/3-2/3	455	6
2/3-1	6,216	88

Table 3. Percentages of landscapes with different grass types.

Type of Grass	Number of Sites	Percent of Sites
St. Augustine	3,693	60%
Mixed	1,663	29
Bermuda	434	8
No grass	185	3
Buffalograss	40	<1

The small number of xeriscapes found in the large cluster sample of the Austin area revealed xeriscape to be rare. At most, six percent of landscapes can be classified as xeriscapes from limited turf area (Table 2) and only four percent can be classified as xeriscapes from no grass or Buffalograss (Table 3).

The inclusion of water efficient Bermuda grass as a xeriscape grass increases the fraction of xeriscape landscapes to 12 percent. The inclusion of both Bermuda and mixed grass with the traditional xeriscape grasses increases the fraction of drought resistant landscapes to 40 percent.

Statistical Analysis Techniques

Descriptive and inferential statistical techniques were used to examine the data.

Basic Descriptive Statistics - The mean (average) water consumption, uncontrolled for other factors, provides a gross estimate of what a typical home with a given grass type consumes in Austin. The analysis of the mean values of other predictors by grass type reveals the average indoor consumption, house value, and irrigation method that is associated with each grass types.

Correlation - Correlation coefficients reflect the extent to which two variables are associated. The correlation coefficient can range from +1.0 to -1.0. A value of 1 shows a perfect positive association, a value of -1 shows a perfect negative association, and a value of 0 indicates no association. Greater magnitudes in either direction indicate stronger levels of covariation. Correlation coefficients are symbolized by "r." A correlation between predictors shows the amount of association between them.

A positive correlation between two predictors suggests that they may explain overlapping information about the outcome. A partial correlation reveals the correlation between a predictor and an outcome, while statistically removing the influence of other predictors.

In the applied social and behavioral sciences, first order correlation coefficients rarely exceed .50 and are typically around .35. Correlation coefficients less than .30 are considered weak; those between .30 to .40 are generally viewed as moderate; and coefficients greater than .50 are considered strong.

Multiple Regression - Multiple relationships among sets of predictors and outcomes can be examined using this inferential statistical technique. Multiple regression computer programs generate the "best-fitting" regression equations that use the values of the predictors to estimate the values of the outcome. The fitted equation minimizes the least squared distance between the equation and the observed data. Parameter estimates and confidence intervals for those estimates can be generated for the terms in the regression equation. The researcher can draw inferences about the impacts from different predictors on the outcome from the magnitude of the terms in the model and their confidence intervals. Multiple regression analysis can statistically remove or control other influences (income level and irrigation method) while showing the impact of a specific predictor on an outcome. In regression, multiple models exist to describe a single data set.

An important statistic from a regression model is the multiple correlation coefficient (r-squared). This statistic shows the amount of information explained by the model. In previous studies of water conservation, r-squared values of .30 to .40 have been found (Bruvold and Mitchell, 1993; Kruta, 1994; California, 1992). The square root of r-squared (r) can be viewed as a multiple correlation coefficient.

Results

The landscape and questionnaire data was analyzed by group comparisons, correlations, and regression analyses. The landscape sample was the primary data base for examining the xeriscape-water use relationship. The questionnaire sample was used to explore other factors affecting water consumption and to analyze chemical use. Key findings from each of these analyses are summarized on page 25.

Water Consumption by Grass Type for the Landscape Sample

The mean water consumption of homes with a water conserving turf was 418 gpd for Buffalograss, 456 gpd for no grass (all shrub bed), 479 gpd for Bermuda, and 393 gpd for mixed grass. The mean water consumption of traditional turf, (i.e., St. Augustine grass), was 596 gpd. There is a 150 gpd difference between St. Augustine and the no grass/buffalo grass (approximately 25 percent). The largest difference (203 gpd) is between St. Augustine and mixed grass. [Note: the conclusions that could be drawn from these results changed when irrigation method or house value were statistically removed. If this study had ***not*** used multivariate statistical techniques, it would have concluded that mixed grass landscapes used the least water of any landscape choice.]

Descriptive Statistics of the Predictors by Grass Type

Table 6 shows the mean values of the non-landscape predictors by grass type. These group differences and the correlation coefficients in Table 7 show that the type of grass in a landscape is related to winter consumption, house value, and irrigation method.

- Traditional landscapes (St. Augustine) are associated with high income areas (r = .19) and underground irrigation systems (r = .33).

- Mixed grass landscapes are associated with lower income areas (r = -.16) and landscapes without irrigation systems (r = -.21).

- No grass landscapes, St. Augustine grass, and Bermuda grass on the average have similar house values.

- Buffalograss landscapes have low market penetration and are associated with higher income areas.

Mean Values of Water Use and Predictors by Grass Type

Grass	Summer Consumption (gpd)	Winter Consumption (gpd)	Percentage with a Irrigation System	House Value Estimated from Cluster Membership	Number of Sites
St. Augustine	596	253	30 %	87,000	3,693
Without St. Augustine	415	204	13 %	75,000	2,322
No Grass	456	281	31 %	89,000	185
Buffalo-grass	418	253	15 %	120,000	40
Bermuda	479	226	21 %	81,000	434
Mixed Grass	393	193	9 %	71,000	1,663
Total Average of Sites	564	234	23 %	82,000	6,015

Table 4. Average water consumption and predictors by grass type. [Note: the house value is estimated from cluster membership].

Mean Water Consumption by Irrigation Method and Grass Type

The mean water consumption by irrigation method and grass type shows the influence of irrigation method on water consumption. These descriptive statistics indicate that drought resistant grasses consume less water than St. Augustine (Table 5). The reduction in consumption between drought tolerant and St. Augustine grass types is 128 gpd (27%) in homes without irrigation systems and 51 gpd (7%) in homes with irrigation systems. All drought tolerant grasses, except Bermuda with irrigation systems, consumed substantially less water than St. Augustine landscapes. [Note: this breakdown does not statistically control for winter water consumption or other predictors.]

Correlation Analysis of the Landscape Data Set

The first order correlation and partial correlation results, controlling for indoor use and house value, are shown in Table 6. Key findings from this analysis are:

- Winter consumption, house value (estimated by geographic location), and irrigation systems have strong positive correlations (greater than .40) with water use.
- St. Augustine grass has a positive association with water consumption (r=.22).
- St. Augustine grass has a positive association with house value (r=.13).
- Mixed grass has a negative association with water consumption (r=-.20).
- Mixed grass has a negative association with house value (r=-.16).
- The predictors of winter consumption, house value (geographic location), irrigation systems, and St. Augustine are positively correlated. Positive correlations among predictors indicate that they contain similar or redundant information about the outcome.
- Partial correlations controlling for winter water consumption show a similar relationship between the predictors and outcomes. The partial correlations controlling for house value show that winter use, grass type, and irrigation system are uniquely related to summer water consumption.

The overall pattern of coefficients suggests that the predictors of grass type, house value, irrigation method, and winter consumption are the best predictors of summer water consumption. To more precisely disentangle the predictor-outcome relationships and to determine the magnitudes of association, a regression procedure was performed.

Irrigation Method	Grass Type	Mean Summer Consumption (gpd)	Number of Sites	Standard Deviation of Group
No Irrigation System	St. Augustine	480	2,573	307
	All Grasses Except St. Augustine	352	1,996	241
	Bermuda	359	342	262
	Mixed Grass	350	1,503	234
	Buffalograss	407	31	161
	No Grass	345	126	277
Irrigation System	St. Augustine	860	1,131	555
	All Grasses Except St. Augustine	809	261	581
	Bermuda	926	92	555
	Mixed Grass	793	160	630
	Buffalograss	471	5	143
	No Grass	696	59	468

Table 5. Mean water consumption by irrigation method and grass type.

	Irrigation System	Mixed Grass	Buffalo Grass	Augustine Grass	Bermuda Grass	No Grass	House Value	Winter Water Use
Summer Water Consumption	**.44**	**-.20**	**-.02**	**.22**	**-.03**	**-.03**	**.40**	**.41**
Summer Water Use Controlling for Indoor Use	.40	-.19	-.01	.21	.02	-.05	.39	——
Summer Water Use Controlling House Value	.35	-.17	-.04	.21	-.05	-.03	——	.35

	Irrigation System	Mixed Grass	Buffalo Grass	Augustine Grass	Bermuda Grass	No grass	House Value	Winter Water Use
Winter Water Consumption	**.20**	**-.06**	**-.01**	**.05**	**-.02**	**.03**	**.14**	
House Value (Location -1/0/1)	**.33**	**-.16**	**.03**	**.13**	**-.01**	**.04**		
No Grass	**.03**	—	—	—	—			
Bermuda Grass	**-.02**	—	—	—				
St. Augustine	**.19**	—	—					
Buffalograss	**-.02**	—						
Mixed	**-.21**							
Irrigation								

Table 6. Correlation matrix for the landscape data set.

Multiple Regression Analysis

Multiple regression disentangles the effects of correlated predictors on an outcome. In this study, multiple regression "adjusted for" (statistically controlled) the geographic location (house value), indoor use, and irrigation differences associated with the different grass types. Regression analysis enables a given predictor-outcome relationship to be evaluated while the influences from other predictors are statistically removed. After statistically removing the influence of wastewater consumption (winter consumption), irrigation system, and geographic location, the regression results (Table 7) indicate the following:

- Buffalograss and no grass landscapes predicted approximately 170 gpd less consumption than traditional St. Augustine sites. The 95 percent confidence interval for Buffalograss (2 standard deviations) is from 57 gpd to 290 gpd, and the interval for no grass is from 125 gpd to 221 gpd. The wide confidence interval for Buffalograss is due to the small number of sites using Buffalograss. Bermuda grass and mixed grass landscapes predicted approximately 90 gpd less than St. Augustine with narrow confidence intervals.

- The presence of an irrigation system increased predicted water consumption by 214 gpd with a 95 percent confidence interval of 192 gpd to 236 gpd.

- For a typical middle income home without an irrigation system, the regression equation predicts a 31 percent reduction in consumption for homes with Buffalograss or no grass compared to traditional St. Augustine landscapes. For an upper income home with an irrigation system, the percentage decrease is 16 percent. For a middle income home, the presence of an irrigation system is associated with a 38 percent increase in consumption.

- Since statistically significant interaction terms were not found between grass type and irrigation method or geographic location, the savings from xeriscaping appears to be constant over all house values and irrigation methods. Therefore, the percentage savings from xeriscaping will be greater in lower and middle income areas without irrigation systems because the base rate of consumption tends to be smaller.

- Geographic location (house value) has a strong relationship to water consumption. Parameter estimates for the influence of geographic location on water consumption range from 324 gpd in high income areas to -161 gpd in low income areas with narrow confidence intervals.

- Homes with larger grass areas tend to consume more water. However, the standard error (27.6 gpd), low t-statistic (1.8), and high chance of a sign reversal (alpha=.07) suggest that this term should not be in the regression model. See Appendix E for a summary of other regression results.

- Forty-one percent (r-squared =.41) of the variation in summer water consumption can be explained with data on grass type, geographic location, indoor use (winter consumption), and irrigation method. About 40 percent of the multiple r-squared value is due to winter consumption, 40 percent is due to geographic location, 10 percent is due to irrigation systems, and 10 percent is uniquely due to grass type.

Parameter Estimates of Predictors of Summer Water Consumption

Predictors	Parameter Estimate [a]	Standard Error [b]	T-Statistic for True Parameter Equals 0 [c]
Intercept Term	**359 gpd**	**11**	**31.8**
Winter Consumption (gpd)	**0.61**	**0.02**	**31.9**
Irrigation System (0/1 indicator)	**214 gpd**	**11**	**19.8**
Grass Predictors (Xeriscape)	The grass type is an indicator 0/1 variable with St. Augustine as the comparison group. The partial r-squared for the grass predictors is **.035**.		
No Grass in Landscape	**-173 gpd**	**24.3**	**-7.2**
Buffalograss	**-174 gpd**	**58.4**	**-3.0**
Bermuda Grass	**-81 gpd**	**16.3**	**-4.9**
Mixed Grass	**-98 gpd**	**9.8**	**-10.0**
Geographic Location (House Value)	The location of the house is an indicator variable with middle income area in far North Austin as the reference group. The r-squared partial for location is **0.165**.		
Very High Income Areas in North Austin	**324 gpd**	**17.8**	**18.2**
High Income Areas in North Austin	**176 gpd**	**14.5**	**12.1**
High Income Areas in South Austin	**17.2 gpd**	**13.8**	**1.3**
Middle Income Areas in South Austin	**-110 gpd**	**12.5**	**-8.9**
Low Income Areas in North Austin	**-116 gpd**	**16.9**	**6.9**
Low Income Area in South Austin	**-161 gpd**	**25.7**	**-6.3**
Other Lower Income Areas	**-141 gpd**	**20.5**	**-6.9**

F-Statistic Value for the Model [d] = 299.3 Degrees of Freedom [e] = 15 (model), 5996 (Error)

Total R-Squared [f] = 0.41 R-Squared Adjusted [g] = 0.41 Max VIF [h] = 1.42

Number of sites visited per term in equation = 400 Multiple correlation coefficient (r) = 0.64

Table 7. Regression model of best fit for the landscape sample.

a. Value of the term in the fitted linear model.
b. Estimate of the standard deviation in the parameter estimate.
c. T-statistic that the sign of the term is wrong. All estimates are statistically significant (alpha=.05) except a high income area in south Austin.
d. Value of F-statistic for all terms in the model.
e. Number of terms in model and data points.
f. A measure for the amount of outcome variability explained by the set of predictors in the regression equation.
g. R^2 adjusted for the number of terms in the model.
h. A measure of the multi-collinearity in the model (A good model should have a maximum VIF of less than 2).
i. R-squared partial for irrigation systems is .04.
j. R-squared partial for winter consumption is .17.

Questionnaire Sample

The questionnaire data set contained additional predictor information on 270 sites subsampled from the large landscape data set (see Appendix B). The questionnaire data included outdoor chemical use, money spent maintaining the landscape, time spent landscaping, and method of irrigation scheduling. Also, the study team collected appraised house value and lot size information on all sites that returned their questionnaire.

Since the questionnaire was mailed by the categorizations of xeriscape, partial xeriscape, and traditional landscape based on plant bed areas and grass type, these predictors were used in the statistical analysis. When using the grass type predictor, the effective size of the sample is reduced because most of the sites in the subsample have St. Augustine grass (170 out of 270). Due to the small number of non-St. Augustine landscapes in the sample, a single classification (1 representing St. Augustine and 0 for any other grass) was used in the analysis.

Descriptive Statistics by Xeriscape Classification and Grass Type

As shown in Table 8, St. Augustine is associated with higher mean water consumption, with the value of other predictors being similar. Xeriscapes are associated with higher water use, higher house value, and greater money spent landscaping, but like the results presented in Table 4 (page 16), the influence from other predictors is not controlled. Again, the simple method of analysis with a comparison of mean values produces an incomplete description of the problem due to not controlling for important predictors.

Correlation Analysis for Chemical Use and Water Consumption

The first order and partial correlations between the predictors and outcomes are shown in Table 9. Key findings from this analysis are:

- Money spent landscaping (r=.46), geographic location (r=.41), house value (r=.38), winter water use (r=.56), and irrigation systems (r=.45) have strong first order correlations with water consumption. These predictors also have a strong first order correlations with each other.

- The predictor of xeriscape grass (any grass type other than St. Augustine) has a moderately negative association with water consumption (r=-.29).

- The very high correlation (.65) between assessed house value and geographic location (-1, 0, 1 scale) suggests that the eight blocking factors for geographic location provide a good approximate measure or proxy variable for house value in the landscape data set analysis.

- Money spent landscaping (r=.33) has the strongest correlation with chemical use.

- St. Augustine grass is a better predictor of chemical use than the xeriscape categorization used to mail the questionnaire (r=.23 versus r=-.03 and -.06).

	Summer Water Use (gpd)	Winter Water Use (gpd)	Irrigation System (%)	House Value ($ 1000)	Lot Size (Sq. ft.)	Money Spent Landscaping (1-5 scale)	Chemical Use	Number of Sites
Landscape sample	513	243	28	82	———	———	———	6015
Questionnaire sample	556	250	26	80	9600	2.4	2.3	270
Sites with St. Augustine	603	253	34	82	9500	2.5	1.8	170
Sites without St. Augustine	443	233	13	77	9800	2.3	2.6	100
Xeriscape	633	253	38	105	11500	2.7	2.2	83
Partial Xeriscape	433	216	14	70	9000	2.0	2.1	85
Traditional Landscape	589	263	26	67	8528	2.4	2.5	102

Table 8 . Mean values of predictors and outcomes by xeriscape classification and grass type.

Summer Water Consumption	Time	Money	Lot Size	House Value	Geographic Location	Pool	Xeriscape Grass	Irrigation	Winter Water
Summer Water Use	.16	.46	.09	.38	.41	.24	-.29	.45	.56
Removing Winter Water Use	.13	.31	.13	.35	.46	.20	-.25	.35	——
Removing Money	.06	——	.05	.25	.31	.20	-.23	.32	.45

The influence of winter water use and money spent landscaping is "removed" by using partial correlations.

Water Consumption	Time	Money	Lot Size	House Value	Geographic Location	Pool	Xeriscape Grass	Irrigation	Winter Water Use
Winter Water Use	.06	.40	-.05	.15	.03	.13	-.15	.29	
Irrigation Systems	.09	.40	.11	.49	.39	.23	-.31		
Xeriscape Grass	-.16	-.20	.01	-.11	-.11	-.06			
Pool	.06	.15	-.01	.21	.19				
Geographic Location (-1,0,-1)	.07	.31	.21	.65					
Tax Record House Value	.03	.36	.16						
Lot Size	.05	.07							
Money Spent Landscaping	.25								
Time Spent Landscaping									

Chemical Use	Chemical Use	Organic Use	Money Spent	House Value	St. Augustine	Xeriscape	Partial Xeriscape
Partial Xeriscape							
Xeriscape							——
St. Augustine						——	——
House Value					.06	.40	-.18
Money Spent				.39	.18	.18	-.20
Organic Use			.22	.11	-.07	.13	.09
Chemical Use		.11	.33	.21	.21	-.03	-.06

Table 9: Correlation matrix for Questionnaire data set.

Multiple Regression Analysis

Regression Results for Water Consumption

These findings about water consumption are based on the regression model of best fit. For a detailed explanation of additional regression equations, see Appendix E.

- A difference in water consumption of 190 gpd with a standard error of 62 gpd was observed between St. Augustine and any xeriscape grass (Buffalograss, no grass, St. Augustine, mixed, and Bermuda). The value of this parameter is similar to the results of Buffalograss and no grass predictors in the landscape data set.

- Lot size and tax records of house value were not statistically significant predictors when geographic location was included in the model. These factors are somewhat interchangeable as predictors.

- The categorization of xeriscape, partial xeriscape, and traditional landscape predictor (a combination of plant bed area and grass type information) was not as good a predictor of water consumption as grass type alone.

- Money spent per year for landscaping was found to have a strong association with water consumption. The difference between a high and low amount of money spent (mean ± 1.5 standard deviation of predictor) corresponds to a 247 gpd increase in predicted use.

Regression Results for Outdoor Chemical Use

- Money spent per year on landscaping was associated with increased frequency of chemical use (Table 11). These results provide evidence of a clear relationship between landscape expenditures and the consumption of lawn care products ($r = .33$).

- St. Augustine grass was found to be associated with increased frequency of chemical use ($r=.21$). With money spent landscaping and St. Augustine grass terms in the model, additional landscape or demographic predictors were not statistically significant. Together, these two predictors accounted for thirteen percent of the variation in chemical use (multiple r-squared= .13; multiple r= .36). This low value suggests that other factors will be important to describe the frequency of chemical use.

- St. Augustine landscapes are more likely to use lawn fertilizers such as Scotts, Fertilome, and Hi-Yield. See Appendix F for detailed information about the types of lawn care products used.

Parameter Estimates of Predictors of Summer Water Consumption

Predictors	Parameter Estimate	Standard Error	T-Statistic for True Parameter Equals 0
Winter Consumption (gpd)	.48	.05	9.05
Irrigation System (0/1 indicator)	127 gpd	73	1.74
Any Xeriscape Grass Including No Grass (0/1 indicator)	-190 gpd	62	3.05
Money Spent Landscaping (1-5 Scale)*	82.5 gpd	35	2.39
Pool on Landscape (0/1 indicator)	175 gpd	89	1.96
Lower Income Areas (geographic location)	-194 gpd	68	-2.83
Higher Income Areas (geographic location)	308 gpd	76	4.02
Intercept	267 gpd	91	2.92

F-Statistic Value for the Model = 40.1 Degrees of Freedom = 9, 261
R-Squared = 0.52 R-Squared Adjusted = 0.51 Max VIF = 1.72
Sites per Term in Model = 34 Multiple Correlation Coefficient (r) = 0.72

Table 10. Regression model of water consumption using questionnaire predictors.

Parameter Estimates of Predictors of Chemical Use

Predictor	Parameter Estimate (Number of Chemical Applications 0-9 scale)	Standard Error	T-statistic
Intercept	0.53	0.32	1.6
Money Spent (1-5 Scale)*	0.59	0.12	4.8
St. Augustine Grass in Landscape (0/1)	0.62	0.24	2.5

F-Statistic=18 Degrees of Freedom = 3,265 Sites per Term in Model =132
R-Squared = 0.13 R-Squared Adjusted= 0.13 Multiple Correlation Coefficient (r) = 0.36

Table 11. Regression model of chemical use.

* The mean value of money spent landscaping is 2.4 with a standard deviation of 1.0.

Key Findings

- Buffalograss and no grass xeriscapes are associated, on the average, with approximately a 30 percent (175 gpd) reduction in water consumption as compared to St. Augustine at the most central tendency of the water consumption distribution.

- Although classified as low-water use, common Bermuda and mixed grasses are not generally viewed as xeriscape grass in other studies; in this study, they are associated with approximately a 15 percent (90 gpd) reduction in water consumption.

- Contrary to the finding produced by the Phase I Report, lot size did not moderate the relationship between xeriscaping and water consumption. Across all lot sizes, the absolute reduction in water consumption associated with xeriscaping remained relatively constant. However, the percentage saved tends to decrease as the predicted consumption increases with house value.

- Irrigation systems are associated with approximately a 38 percent (214 gpd) increase in water consumption.

- After controlling for other factors, the highest income areas are associated with a 57 percent (324 gpd) increase in water consumption as compared to the mid-range income areas; conversely, the lowest income areas are associated with a 28 percent (161 gpd) decrease in water consumption.

- In the large data set on landscapes (N = 6,015), forty-one percent (r-squared = .41; Multiple r = .64) of the total amount of *variability* in summer (outdoor) water consumption was explained by the predictors of winter (indoor) consumption, grass type, irrigation system, and geographic location. Winter consumption and geographic location each explained approximately 40 percent of the accounted variability in summer water consumption (partial r-squares = .17 and .16). The set of xeriscape grass types, as well as irrigation systems, each explained 10 percent of the accounted variability in summer water consumption (partial r-squares = .04).

- The amount of money spent per year for landscaping and the presence of a swimming pool tend to be associated with increased water consumption with an average increase of 36 percent and 31 percent respectively. In the relatively small questionnaire data set (N = 270), these factors helped increase the amount of *variability* explained in summer water consumption to 52 percent (r-squared = .52; r = .72).

- A similar analysis of water consumption data from the summer of 1993 using the landscape data set showed that underground irrigation systems and income level had a larger influence on water use in a dry year (See Appendix G).

- St. Augustine landscapes showed a weak association with greater frequency of outdoor chemical usage.

Answers to Research Questions

Question 1- Is there a 40 percent average reduction in water consumption associated with xeriscape practices?

Answer- No, the reduction in observed water consumption is approximately 30 percent. This reduction in predicted use is similar to the magnitude of reductions found by the North Marin Residential Study that used multivariate analysis (see page 6).

Question 2- Do additional social-economic or landscape factors influence the water savings from xeriscaping?

Answer- Yes, but the reduction in water consumption from xeriscaping is constant as total predicted consumption increases. The percentage savings from xeriscaping decreases as predicted water consumption increases. In addition to the base rate of indoor consumption, the factors that *increase* water consumption are:

- Increased house values or more affluent neighborhoods (57%);
- Automatic Irrigation Systems (38%);
- Swimming Pools (36%);
- Large Landscape Expenditures (31%).

Question 3 - Is xeriscaping associated with reduced chemical use?

Answer- Not clearly though St. Augustine grass is weakly associated with a greater frequency of outdoor chemical use. In addition, the lawn and garden products associated with St. Augustine grass tend to be more environmentally harmful (see Appendix F).

Preliminary Cost-effectiveness Analysis of a Xeriscape Rebate Program

Based on the regression solutions, xeriscaping (Buffalograss or no grass) corresponds to about a 170 gpd reduction in predicted water consumption. The reduced consumption associated with xeriscaping appears to be constant over all house values and irrigation methods. Based on these findings, a preliminary cost-effectiveness analysis for a xeriscape rebate program is developed below. The preliminary cost-effectiveness analysis is presented to clarify two important unknown factors that need to be determined in calculating a long-term return on investment: free-ridership and a social multiplier.

The research in this study clearly demonstrates that xeriscapes have the potential for reducing water consumption by at least 16 percent and in many cases 31 percent. However, numerous factors about program implementation not included in this study can influence the savings and the costs associated with a xeriscape rebate program. Through the rebate process, a home owner may learn about appropriate irrigation as well as the lower water requirements of the rebated plants and subsequently change watering habits. On the other hand, a home owner may not change watering habits after the rebate, and the additional money spent landscaping may result in increased consumption presumably to protect the new plant investment. Because of the difference in customer behavior, the cost analysis necessarily includes a substantial amount of uncertainty. This uncertainty in the water savings is shown in the analysis by the range of savings estimates from 130 gpd to 180 gpd. Finally, the problem of free ridership, individuals receiving the rebate who would have installed a xeriscape without the rebate program, may decrease the true savings per amount of money spent on the program. The free ridership in the Mesa, Arizona program is estimated to be 61 percent (Testa and Newton, 1993). The free ridership in the Austin program should be smaller due to the lower market penetration of xeriscaping. The free ridership factor in the analysis is calculated by multiplying the total water savings by the speculated fraction of individuals who would choose to xeriscape specifically as a result of the rebate program.

Does xeriscaping reduce water consumption enough to justify a large scale program to promote it? In Table 12, the study team presents two alternative scenarios of the relationship between the water saved by xeriscaping and costs of a xeriscape rebate program. For the optimistic savings estimate, a xeriscape rebate program would produce a positive rate of return of \$ 253 to \$ 475 per unit installed depending on the interest rate. As shown in rows A1 and A2 in Table 14, a xeriscape rebate program that produced conservative savings would yield a negative return on investment (-\$82 to -\$150).

However, a multiplier effect should be anticipated. A multiplier effect refers to the rate of increase in the adoption of a new product that occurs because of social influence. Innovations tend to be adopted through social diffusion (individuals learning about the product from others and being encouraged by others to adopt it). If xeriscape programs are designed and implemented to capitalize on social influence, then the resulting multiplier could contribute to a very positive return on investment in the long-term. At this time, the study team estimates the market acceptance of Buffalograss xeriscapes at 0.5 percent and no grass xeriscapes at 3 percent to 6 percent depending on the definition of a no grass landscape. The small number of xeriscapes found in Austin suggests xeriscape is not yet widespread, and hence a multiplier effect may be slow in coming. Likewise, the small market share suggests that there may be a limited initial demand for this type of landscape. Another explanation of the low market share of xeriscaping is that xeriscaping is relatively new and the majority of home owners may not have known about it when they installed their landscape.

The market effectiveness of xeriscaping will determine if social diffusion produces a positive multiplier due to a positive reaction, or a negative multiplier due to a negative reaction. The success of the Xeriscape Garden Club, the increasing numbers of application to the "*Xeriscape-It*" rebate program, the popularity of the Xeriscape School, and other recent City of Austin xeriscape initiatives suggest that the popularity of xeriscapes in Austin is on the rise (Chaumont and Gregg, 1993; Pego, 1993). Given these positive responses to the City of Austin's xeriscape program and positive feedback from a customer questionnaire of rebate participants (see Appendix H), the multiplier effect is most likely positive. As shown in row B2, with a multiplier effect of 2 (meaning each xeriscape home owner influences an additional home owner to xeriscape) and a free ridership of 35 percent, a rebate program will result in a long term positive rate of return on an investment of $68 per residential site for a conservative savings estimate.

	Optimistic Savings Estimate	Conservative Savings Estimate	Source of Estimate
Estimates of Water Saved			
GPD saved per unit	180	130	Phase II study
Number of days of savings per year	120	90	
Total gallon saved per unit-year	21,600	11,700	
Estimates of Value of Water Saved			
Value of 1000 gallons of water save to city	2.5	2.18	(COO, 1993)
Annual value of water saved per xeriscape	$ 54	$ 26	
Estimates of Rebate Program Cost			
Cost of Rebate	$ 150	$ 150	Cost estimate of program
Fixed Overhead cost of program	$ 100	$ 150	Cost estimate of program
Total cost per rebate	$ 250	$ 300	
Free-Ridership Percentage (Removes all savings attributed to a site)	0 %	35 %	
Net Present Worth for Each Unit Installed with 20 Year Life			
A1. Interest rate 4%	$ 475	-$82	
A2. Interest rate 8%	$ 253	-$150	
Net present worth for each unit installed with a multiplier at a 4% interest rate (note the multiplier impact is assumed to happen without a time lag when the unit is installed)			
B1. 1.2 multiplier	$ 525	-$22	
B2. 2 multiplier	$ 600	$68	

Table 12. A cost-effectiveness analysis of the financial impact of a xeriscape rebate program.

Social Behavioral View of Xeriscape Promotion

Designing, implementing, and refining xeriscape programs should be guided by a model based on applied social-behavioral sciences (Figure 5). The model is derived from a synthesis of research findings and contributions from the social-behavioral sciences concerning the impact of the social influence processes on conservation attitudes and behavior (Aronson and Gonzales, 1990; Costanzo, Archer, Aronson and Pettigrew, 1986; Geller, Erickson, and Buttram, 1984; Kantola, Syme, and Cambell, 1982; Tompson, 1991).

The model depicts a process of customer involvement and satisfaction moving from a psychological state of receptivity to the objective and subjective payoffs from installing xeriscape and performing xeriscape practices. In addition to the real payoffs, perceived payoffs are the key to strengthening attitudes toward xeriscape and water conservation (Hampton, 1985). Improved attitudes, in turn, have important behavioral consequences such as: 1) intensifying the regularity of newly acquired practices to reduce water consumption, 2) expanding water saving behavior to include other water conservation practices, 3) showing greater concern for environmental protection by reduced outdoor chemical and water use, and 4) promoting the benefits of xeriscape to friends and neighbors. Negative attitudes could have the opposite effect.

In the model, customer receptivity is shown as being influenced by neighborhood and social network communications about landscaping, purchase incentives, and advertising/promotion (public education). Customer receptivity refers to the initial interest in xeriscape or openness to installing a xeriscape and adopting xeriscape practices. Testa and Newton's findings presented at the recent AWWA CONSERV'93 conference attest to the importance of neighborhood influences on decisions to participate in xeriscape programs. A quarter of the participants in the xeriscape rebate program and a third of the control group reported "conformity" to neighborhood standards as an influential factor in the decisions to participate. In the same study, almost half of the respondents (46%) reported the rebate as a factor influencing their decisions to install low water use landscapes. Also, geographic location, which contains some information about neighborhood influences, was a very important predictor in this study.

As implied by the social-behavioral model, customers who set goals to save water are more likely to lower their water use. The idea of assisting conservation-oriented customers with setting realistic goals and providing performance feedback is not new, but thus far has not been adequately researched (Aronson and Gonzalez, 1990; Geller, 1983). However, the research findings about goal setting, feedback, and performance rewards published in the applied psychological literature strongly suggest that these procedures could be leveraged to increase the effectiveness of conservation programs (Chidester and Grigsby, 1984; Locke and Latham, 1984; Tubbs, 1986; Wofford, Goodwin, and Premack, 1992).

Promotion, education, and purchase incentives are the common components of a xeriscape program (Chaumont and Gregg, 1993; Campbell and Saldana, 1993), but the service components which are likely to be the key to long term success are goal setting, feedback, and performance rewards. These service components can influence customer expectations, the performance of xeriscape practices, and other objective and subjective payoffs from a xeriscape program. Ongoing efforts to refine the overall cost-effectiveness of the xeriscape rebate must include evaluation research of additional service components. Also, research should examine attitude-behavior relationships in outdoor water consumption and the role of social influence in adopting landscaping innovations.

Social-Behavioral Model to Guide Xeriscape Research and Program Refinement

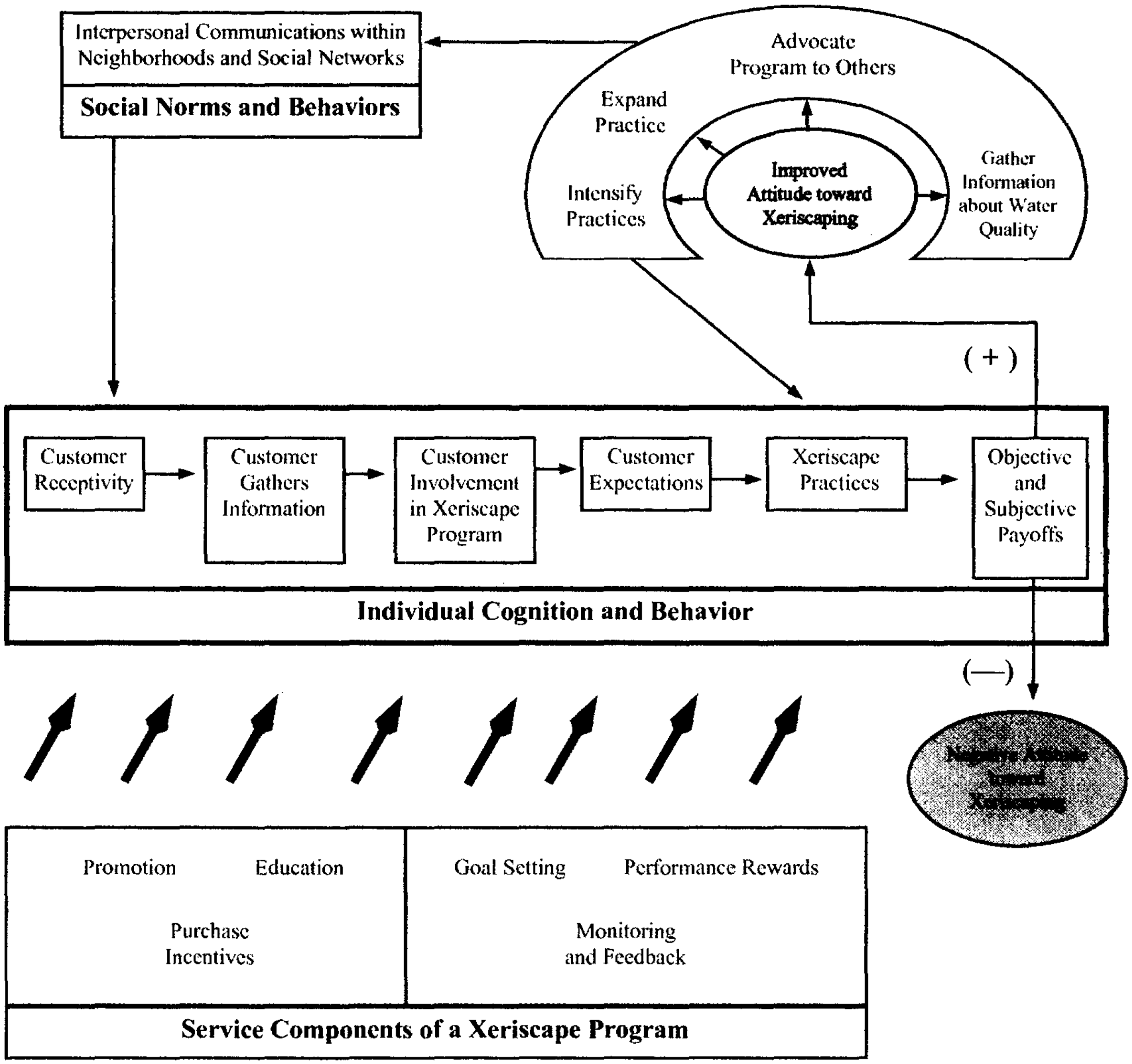

Figure 6. Social-behavioral model to guide future xeriscape research and program refinement.

Public Policy Recommendations

Lowering peak day water consumption by 10 percent by the year 2,000 is a major public policy objective of the City of Austin. To achieve this goal, outdoor residential water consumption must be reduced. Residential customers have the highest peaking factors (3.91), that is the ratio of maximum hourly usage to average hourly usage (Rothstein, 1993). The peaking factor determines the water treatment capacity required to supply an area. From the results of this study, a xeriscape rebate program has the potential to reduce landscape water consumption if implemented correctly. Because the factors affecting the success of a xeriscape program are only starting to be understood, implementation evaluation and outcome evaluation should be continued. Evaluation and program refinement must be integral parts of the xeriscape promotion process (Table 6).

From the Texas Water Development Board's perspective, xeriscaping is one possible method to reduce state-wide urban peak day water demand. Xeriscaping could help to achieve the prediction of a 10 to 15 percent decrease in outdoor water usage stated in the Water For Texas Plan (Texas Water Development Board, 1990). To determine the effectiveness of xeriscaping, the Water Development Board funded this report. An expanded xeriscape initiative could include funding additional studies on the behavioral components of xeriscape promotion, developing standards for xeriscape program evaluations, developing a single estimate of the savings from xeriscape based on the several studies that have been performed (meta-analysis), and providing significant funding for municipalities to establish xeriscape promotion programs. The key to making informed policy choices about xeriscape and other conservation issues will be to recruit and coordinate local municipalities in evaluating their own water conservation programs.

From the City of Austin's perspective, xeriscaping can reduce outdoor water use to help achieve the 10 percent goal outlined in the water conservation plan and council resolutions (City of Austin, 1993; City of Austin, 1990). Since 1985, xeriscape has been promoted through public information programs, rebates, and the Xeriscape Garden Club. The city needs to move from a research and initial program phase to a long term strategic plan. If the pilot rebate program shows substantial savings at a low cost, then a full scale program should be implemented. After implementation, additional evaluation of the program should focus on improving program functions (particularly the service components) and aiding the social diffusion of xeriscape.

For a trial program to be a success, it must produce evidence of substantial water savings (150 gpd) and show preliminary evidence of establishing xeriscape grass as a community standard (market acceptance). However, if only a small change in consumption occurs after the retrofit or if there is limited demand for a rebate program, then the program should be re-evaluated. Thus, the City of Austin should spend a considerable amount of effort developing methods to track xeriscape market acceptance, gather water savings information after a rebate is awarded, and acquire customer feedback (see Appendix H). Customer feedback should include information about the perceived quality of the xeriscape, reasons for xeriscaping, behavioral changes after the rebate, and the service components of a xeriscape promotion program.

State Perspective

Determine Feasibility of Xeriscape

- Establish networks to coordinate initial xeriscape demonstration projects.
- Fund preliminary xeriscape studies.
- Facilitate information exchange.
- Identify the "best practices."

Positive Response from Local Municipalities Encourages the Texas Water Development Board to Support Xeriscape Efforts.

Develop Statewide Promotion

- Provide significant start up funding to support local municipalities with the xeriscape programs.
- Meta Analysis (combining the results of many studies).
- Coordinate efforts to determine the best xeriscape practices.
- Develop MIS (management information system) standards for tracking the effectiveness of xeriscape and other water conservation programs.
- Set standards for program implementation and outcome evaluation.
- Disseminate information about xeriscape.

Local Municipalities (Austin) Perspective

Determine Feasibility of Xeriscape

- Conduct preliminary study of existing landscapes.
- Assess marketability.
- Determine effective methods of xeriscape promotion.
- Identify the "best practices."

Local municipality based on the water savings potential of xeriscaping decides to implement a xeriscape program.

Implement and Refine Service Components

- Promotion
- Education
- Purchase incentives
- Goal setting
- Feedback to the customer
- Performance rewards
- Develop MIS (management information systems) to make data driven policy actions.

Evaluating Initial Program

- Determine market acceptance.
- Determine the reduction in water consumption.
- Determine cost effectiveness.

Based on the data from the initial program, the local municipality determines if a long-term program should be implemented.

Developing Long Term Programs

- Choose the most cost effective service components.
- Set long term goals.
- Establish ongoing Plan-Do-Check-Act Cycles.
- Develop landscape ordinances for new residential and other customers.

Figure 6 . Suggested xeriscape policy action path.

Improving Water Conservation Research

In addressing the development of a statewide evaluation standard for water conservation issues, the Texas Water Development Board should consider these important approaches to improving the quality of water conservation research.

Multivariate Research

This study demonstrates the power of multivariate statistical analysis in examining the factors affecting residential water consumption. Future research on water conservation should examine the complex relationships between multiple predictors and multiple outcomes. Other recent reports in water conservation also demonstrate the advantages to be gained and the erroneous inferences to be avoided by using multivariate analysis (Chestnut and McSpadden, 1991; California Urban Water Agencies, 1993).

Program Service Components

Future xeriscape research and program evaluation studies should consider each of the six service components in the social-behavioral model on page 30.

Social Factors

It is imperative that future research examine the social psychological factors influencing water consumption such as a concern for the environment (Baldassare and Katz, 1992), perceived cost of water, education level about home repair or conservation technology, and money spent landscaping. By including social-psychological factors in future correlational analysis of water consumption, a greater understanding of water conservation behavior will be achieved.

Greater understanding of how water conservation innovations are socially diffused will improve the effectiveness of xeriscape promotion. For xeriscape promotion, social factors of market penetration, perceived quality of the product, and positive/negative feedback from the customer are as important to the water conservation potential as the actual reduction in use. These factors will be key to successfully establishing the product in the market.

Information Exchange

Since research on xeriscape and outdoor residential water use is a relatively new phenomenon, an information exchange among research teams should be encouraged. To support this exchange, we invite communications about this xeriscape project and future water conservation research. For more information, contact James Curry or Tony Gregg:

Environmental and Conservation Services Department
Water Conservation Program
206 East 9th Street Suite 17.102
Austin, Texas 78701

Phone: (512) 499-2461

Xeriscaping: Promises and Pitfalls

Based on the research findings of this report regarding the landscape and social-economic factors associated with xeriscape water savings, a synthesis of these findings with conservation research contributions from applied social-behavioral science, and the preliminary cost-effectiveness analysis, the promises and pitfalls are as follows:

Promises of Xeriscaping

- Xeriscaping offers the potential to reduce residential water consumption during the summer months by an average of 31 percent. This percentage savings from the installation of Buffalograss and no grass xeriscapes is equivalent to approximately 175 gpd per unit.
- Percentage savings (not absolute gpd reductions) in water consumption *larger* than 31 percent will be forthcoming, if xeriscape promotions target market segments in the low to mid-range income neighborhoods without irrigation systems.
- The effectiveness of xeriscape programs can be *enhanced* by designing in the service components of goal setting, monitoring/feedback and performance rewards to supplement the typical components of advertising and promotion, education, and purchase incentives (rebates).
- Even greater water savings may be achieved, as well as a worthwhile return on investments from large scale program development, if the power of social influence is leveraged in future xeriscape promotions.

Pitfalls of Xeriscaping

- If home owners spend additional amounts of time and money landscaping in the rebate process without receiving education from the program about xeriscape and appropriate maintenance, then a xeriscape rebate programs could exert a negative impact on water conservation.
- The percentage savings tends to be *greatly constrained* or completely washed-out by the following landscape and social-economic factors: underground irrigation systems, swimming pools, and adoption in only affluent neighborhoods.
- Neglecting to experiment with additional service components suggested by the Social-Behavioral model (page 30) will likely place a severe limit on the potential water savings that could be achieved through xeriscaping. Although promotion, education, and purchase incentives will be needed to produce the anticipated 31 percent water savings, excessive consumption will continue among a large number of homeowners unless service components can successfully influence individual behavior.
- A xeriscape rebate program may not be sufficient by itself to change the initial market acceptance and long term market penetration of Buffalograss and no grass xeriscapes. Limited customer receptivity (market demand) may pose a significant barrier to achieving the minimal market share necessary to justify xeriscape promotion on solely economic grounds. A disregard for the power of social influence in the designing of xeriscape promotion programs may result in a significant lost opportunity.

Concluding Remarks

We are grateful to the Texas Water Development Board for supporting this research about residential water consumption, chemical use, and xeriscape.

This report on the promises and pitfalls of xeriscaping is the result of applying rigorous and sophisticated methods of data analysis. Although a predictor-outcome framework was constructed in the beginning and guided the statistical analysis, in the early stages the research team was uncertain about where it was going to end up. The interpretive discussions were often long and laborious because of the enormous amount of data and multiple relationships in the data. What made the journey up the mountain a painful but rewarding process was the collaboration among team members from very different professions — engineering to landscape architecture to applied social psychology. As team members contributed their skills and experience to the discussions and report writing, the collaborative work sessions were often extremely spirited. It is our hope that this report will aid policy and program planners as well as water conservation researchers.

Appendix A: References

Appendix A: References

1. Aronson, E. and Gonzales, M. E. (1990). "Alternative Social Influence Processes Applied to Energy Conservation," Chapter 13, in *Social Influence Processes and Prevention*, John Edwards (Ed.), 301-325.

2. Austin, City of (1994). Preliminary Report on the Effectiveness of Irrigation Audits.

3. Austin, City of (1993). <u>Quantifying the Effects of Xeriscape Landscaping on Outdoor Water Use (Phase I)</u>.

4. Austin, City of (1993). <u>Water Conservation Plan</u> (Montgomery Watson).

5. Austin, City of (1990). Council Resolution, December 6.

6. Baldassare, M. and C. Katz (1992). "The Personal Threat of Environmental Problems as Predictor of Environmental Practices," *Environment and Behavior*, 24(5), 606-616.

7. Bennet, Dick (1993). "Residential Landscape Comparison Study," AWWA *Conserv'93 Proceedings*, December, 1725-1732.

8. Brovold, William H. and Patrick R. Mitchell (1993). "Evaluating the Effect of Residential Water Audits," *AWWA Journal,* August, 79-84.

9. California Urban Water Agencies and Planning and Management Consultants (1992). *Evaluation of Urban Water Conservation Programs: A Procedures Manual.*

10. Champbell, Richard and Patricia A. Saldana (1993). "Water Wise Landscaping: A Stategy for Long-term Water Conservation", *AWWA Conserv'93 Proceedings*, December, 1733-1746.

11. Chestnut, Thomas W. and Casey N. McSpadden (1991). "The Evaluation of Water Conservation Programs: What's Wrong with the Industry Standard Approach?, A report Submitted to the Metropolitan Water District of Southern California," Los Angeles CA, January.

12. Chaumont, Lynn and Tony Gregg (1993). "City of Austin Xeriscape Program: A Unique Model of Community Involvement," *AWWA Conserv'93 Proceedings*, December, 1747-1753.

13. Chidester, Thomas and Charles Grigsby (1984). "A Meta-Analysis of the Goal Setting-Performance Literature," *Academy of Management Proceedings*, 202-206.

14. Constanzo, M., Archer, D., Aronson, E., and T. Pettigrew, (1986). "Energy Conservation Behavior: The Difficult Path from Information to Action," *American Psychologist,* 41, 521-528.

15. Geller, E.S., Erickson, J. B., and B. Buttram (1984). "Attempts to Promote Residential Water Conservation with Educational, Behavioral, and Engineering Strategies," *Population and Environment*, 6(2), 96-111.

16. Hamilton, L. C. (1985). "Self-reported and Actual Savings in a Water Conservation Campaign," *Environment and Behavior*, 17(3), 315-326.

17. Hipp, Billy, Alexander, Suzan and Tim Knowles, (1993). " Use of Resource-Efficient Plants to Reduce Nitrogen, Phosphorus, and Pesticide Runoff in Residential and Commercial Landscapes," *Water Science Technology*, Vol.28, (3-5), 205-213.

18. Kantola, S.J., Syme, G.J. and Campbell, N.A. (1982). The Role of Individual Differences and External Variables in a Test of the Sufficiency of Fishbein's Model to Explain Behavioral Intentions to Conserve Water. *Journal of Applied Social Psychology*, 12 (1), 70-83.

19. Locke, E. and G.P. Latham (1984). "*Goal Setting: A Motivational Technique That Works!,*" Englewood Cliffs, NJ, Prentice-Hall, Inc.

20. Lohr, V. I. and L. H. Bummer (1989). "Developing Education Programs to Improve the Awareness of Well-Designed Water-Conserving Landscapes," CELA 1989 Proceedings of Council of Educators in Landscape Architecture Conference (abstracts for oral presentation published; written paper review in progress).

21. National Xeriscape Council Inc. (1991). "The Official Definition and Description of the Seven Principles for Xeriscape Type Landscapes."

22. Nelson, John (1987). "Water Conserving Landscapes Show Impressive Savings," *Journal of the American Water Works Association*, March, pp 35-42.

23. Nelson, John (1994). "Water Saved by Single Family Xeriscapes," Preliminary Draft for AWWA National Conference, New York, June.

24. Pego, David (1993). "Dry Goods by the Yard," Austin American Statesman, September 28, F1, F3.

25. Rothstein, Eric (1993). "Summer Water Demand Patterns in a Southwest City," AWWA Conserv'93 Proceedings, December, 1491-1516.

26. Sokulsky, Kariann and Michael Nieswiadomy, (1993). "The Effectiveness of Xeriscape Practices: Questions Regarding Research Methods, Policy, and Planning," Presented at AWWA *Conserv'93*, December.

27. Testa, Ann and Ann Newton (1993). "An Evaluation of a Landscape Rebate Program," *AWWA Conserv'93 Proceedings*, December, 1763-1775.

28. Timmerman, Deborah (1992). "Back Yard Revolution," *Texas Parks and Wildlife,* February.

29. Thompson, S. and K. Stoutemyer (1991). "Water Use as a Commons Dilemma: The Effects of Education that Focuses on Long-term Consequences and Individual Action," *Environment and Behavior*, (237), 314-333.

30. Tubbs, M. E. (1986). "Goal Setting: A Meta-analytic Examination of the Empirical Evidence," *Journal of Applied Psychology*, 71(3), 474-483.

Appendix B: Xeriscape Questionnaire

City of Austin
Founded by Congress, Republic of Texas, 1839
Municipal Building, Eighth at Colorado, P.O. Box 1088, Austin, Texas 78767 Telephone 512/499-2000

March 30, 1993

Dear Homeowner:

The City of Austin Environmental and Conservation Services Department is conducting a survey of City water customers. Your household has been randomly selected to represent water customers in your area.

The City serves more than 500,000 customers in 225,000 homes and apartments; however, we are sending this survey to only 800 households. For this reason, your help is critical to the success of this survey. We are gathering this data in accordance with a grant from the Texas Water Development Board.

Please take a few minutes to complete the survey and return it to us promptly. For your convenience, we have included a postage-paid envelope.

The survey questionnaire should be completed by the person in your household who does most of the lawn and/or garden care. If you hire a professional gardener or landscaper, please consult with them as needed to complete the survey.

Your answers to the survey will be kept confidential. We will report on overall group results only; **no individual answers will be reported or released.**

Please take a few minutes to complete the survey form and return it to us **within 7 days**. If you have any questions, call Barry Landry or Deborah Phillips at 499-3542.

Thank you in advance for your participation in this important project.

Sincerely,

Tony T. Gregg

Tony T. Gregg, P.E.
Engineer II
Environmental and Conservation Services Department

enclosure

AUSTIN LANDSCAPE SURVEY

THE FOLLOWING QUESTIONS DEAL WITH IRRIGATION. FOR EACH QUESTION, MARK THE ANSWER THAT BEST FITS YOUR USUAL PRACTICE.

1. What method do you use to water outside your home? (If you use a combination, mark the type that you use most.)

_____ a. Hose; by hand
_____ b. Hose-end sprinkler
_____ c. Underground sprinkler system
_____ d. Drip system
_____ e. Other (explain)_____________________

2. During the summer of 1992, approximately how often did you water your lawn?

_____ a. Every day
_____ b. Once every 2-4 days
_____ c. Once every 5-7 days
_____ d. Once every 8-10 days
_____ e. Less often than every 10 days
_____ f. I didn't water last summer

3. During the summer of 1992, how often did you water your planted beds? (shrubs, flowers, groundcovers, etc.)

_____ a. Every day
_____ b. Once every 2-4 days
_____ c. Once every 5-7 days
_____ d. Once every 8-10 days
_____ e. Less often than once every 10 days
_____ f. I didn't water last summer

4. During the summer, how do you determine when to water? (Check all that apply.)

_____ a. I follow a set schedule
_____ b. I usually follow a set schedule, depending on weather
_____ c. I water when the grass or plants look dry
_____ d. I water when it is convenient
_____ e. I follow the City of Austin's voluntary summer water schedule

5. On average, for how long do you water during the summer? If you water your lawn in sections, please mark how long you water each section.

LAWN:

_____ a. Less than 15 min.
_____ b. 15 - 30 min.
_____ c. 30 - 45 min.
_____ d. 45 - 60 min.
_____ e. Longer than 1 hour

SHRUBS/FLOWER BEDS:

_____ a. Less than 15 min.
_____ b. 15 - 30 min.
_____ c. 30 - 45 min.
_____ d. 45 - 60 min.
_____ e. Longer than 1 hour

THE FOLLOWING QUESTIONS RELATE TO THE MAINTENANCE OF YOUR LANDSCAPE. FOR EACH QUESTION, MARK THE ONE ANSWER THAT BEST FITS YOUR USUAL PRACTICE.

6. Who performs the maintenance on your lawn, including mowing, fertilizing, weeding, and pest management ?

_____ a. I do it myself
_____ b. Landscape service
_____ c. Other (list)_____________________

7. **Not counting time spent watering,** about how much time does it take per MONTH to perform the maintenance on your landscape? Include total time spent by you, any landscape service companies, and anyone else who works on the landscape.

_____ a. 0 - 4 hours
_____ b. 4 - 8 hours
_____ c. 8 - 16 hours
_____ d. 16 - 24 hours
_____ e. More than 24 hours
_____ f. I don't know

8. Please indicate which, if any, of the following pests you have found to be a problem around your home. Mark as many types as are a problem.

_____ Aphids
_____ Mealybugs
_____ Pillbugs
_____ Scale insects
_____ White Flies
_____ Unidentified or unknown types of pests
_____ Other_____________________
_____ None -- pests are not a problem

9. **During 1992, how often did you apply each of the following to your landscape?**

a. **Chemical Pesticides:** (not counting flea or fire ant controls)
______ a. Once or twice
______ b. Three or four times
______ c. More than four times
______ d. Not at all
______ e. I don't know

b. **Natural/Biological Pest Controls:**
______ a. Once or twice
______ b. Three or four times
______ c. More than four times
______ d. Not at all
______ e. I don't know

c. **Chemical Weed Killers:**
______ a. Once or twice
______ b. Three or four times
______ c. More than four times
______ d. Not at all
______ e. I don't know

d. **Chemical Fertilizers:**
______ a. Once or twice
______ b. Three or four times
______ c. More than four times
______ d. Not at all
______ e. I don't know

e. **Organic Fertilizers**
______ a. Once or twice
______ b. Three or four times
______ c. More than four times
______ d. Not at all
______ e. I don't know

10. How do you determine when to use chemicals on your lawn and landscape?
______ a. According to my own set schedule
______ b. Only occasionally, when pests or weeds are a problem
______ c. I just follow the instructions on the package
______ d. I don't use any chemicals
______ e. I don't know

11. Please read the following lists of common lawn and garden care products and check all that are used around your home.

Pest Controls
(not counting flea or fire ant controls)
___ Altocid
___ Bt
___ Exhibit
___ Hinder
___ insects (such as ladybugs)
___ Malathion
___ Precor
___ Pyrethrin
___ Safer Soap
___ Thuricide
___ Diazinon
___ Dursban
___ Sevin
___ Diatomaceous earth
___ other (list) ___________

Weed Killers
___ Balan
___ Dacthal
___ Eptam
___ MSMA
___ NpHuric
___ Round-Up
___ Weed-B-Gon
___ Weed & Feed
___ other (list) ___________

Fertilizers
___ Austinite
___ blood or bone meal
___ compost
___ Dillo Dirt
___ Miracid
___ Milorganite
___ Miracle Gro
___ Osmocote
___ Lawn fertilizers such as Scotts, Fertilome, Hi-Yield, etc.
___ Super Bloom
___ Sustain
___ other (list) ___________

THE FOLLOWING QUESTIONS RELATE TO THE COSTS ASSOCIATED WITH YOUR LANDSCAPE. FOR EACH QUESTION, MARK THE ANSWER THAT BEST REFLECTS YOUR SPENDING.

12. **Not including your water bills,** about how much do you spend EACH YEAR on your landscape? (Including plants, seed, fertilizer, soil, mowing and maintenance, etc.)
______ a. $0 - $50
______ b. $51 - $200
______ c. $201 - $500
______ d. $501 - $1000
______ e. More than $1000

13. About how much did you spend to install or improve your landscape when you first moved into your present home?
______ a. $0
______ b. $1 - $100
______ c. $101 - $500
______ d. $501 - $1000
______ e. $1000 - $5000
______ f. More than $5000

THE REMAINING QUESTIONS DEAL WITH YOU AND YOUR HOUSEHOLD. FOR EACH QUESTION, MARK THE ANSWER THAT BEST FITS YOUR SITUATION.

14. When you first moved into your home, did you make any changes to the landscape?
______ a. No, I left it as it was
______ b. Yes, I made a few changes (less than 25% of the landscape)
______ c. Yes, I made major changes (25% – 75% of the landscape)
______ d. Yes, I did a complete renovation (75% – 100% of the landscape)

15. Does your home have any of the following? (check all that apply)
______ a. Swimming pool
______ b. Outdoor hot tub / Outdoor jacuzzi
______ c. Outdoor water feature (fountain or pond)

16. How do you get most of your information about lawn and landscape care?
______ a. TV
______ b. Radio
______ c. Newspaper
______ d. Magazine
______ e. Nursery
______ f. Neighbors/friends
______ g. Landscape service company
______ h. other (list) ______________________

17. Are you...
______ Female
______ Male

18. What is your age?
______ a. 18-25
______ b. 26-35
______ c. 36-45
______ d. 46-55
______ e. 56-65
______ f. Over 65

19. How many people are currently living in your home?
______ a. 1
______ b. 2
______ c. 3-4
______ d. 4-5
______ e. More than 5

20. Please fill in your address: (optional) ____

21. Please provide any comments you have regarding City environmental services.

Thank you for participating in this survey.
Please place this form in the provided postage-paid envelope and drop it in the mail.

Appendix C: Self-Reported Plant Watering

Appendix C: Self-Reported Plant Watering

In the questionnaire survey, the study team asked individuals about the length of watering time and the frequency of watering of their plant bed and turf areas. The study team translated the five categories of possible responses for each question into a score that represented the best estimate of an average response value. Outdoor water consumption should be a simple function of frequency of applications and water consumption per application.

The length of watering is not an accurate estimate of water consumed per application due to the large difference in flow rates between systems. Also, the question asked about watering each section (a term that is only well defined for homes with underground systems), so some individuals with hose-end or hand-held irrigation methods might have interpreted the question as meaning the time spent watering the entire landscape. Because the length of time watering is not an accurate estimate of the water consumption per application, the study team primarily examined the frequency of use and assumed that the amount of water per application is constant. About 1 inch per application is correct for the Austin area.

The results of this analysis show:

- Individuals with automatic irrigation systems water more frequently than those who water by hand or hose-end. The magnitude of the difference is large enough to explain the finding that irrigation systems increase water consumption (Table A).

- St. Augustine is watered more frequently than other grasses (Table B).

- Self-reported information provides a good set of predictors for a regression model to describe water use (Table C and Table D). The r-squared value is similar to the model of best fit in the report. The partial r-squared shows that frequency of use describes a large portion of the variability (r-squared partial = .12), over 25 percent of the explained variance. Included the frequency of water term in the regression model reduces the magnitude of the St. Augustine grass and irrigation terms. The study team interprets this reduction as showing frequency of watering can explain the reason for St. Augustine and irrigation systems predicting high water consumption. This finding suggests that educating the customers about how to water their landscape is a critical service component to a xeriscape program.

- The predictor of days between watering has a strong negative correlation with water use (-0.4). Days between watering also has a strong negative correlation to St. Augustine (-0.36) and underground irrigation (-0.3). These correlations suggest that one reason St. Augustine grass and underground irrigation are predictors of high water consumption is that landscapes with St. Augustine or underground irrigation are more frequently watered.

- Plant beds are watered with the similar frequency as turf areas (Table A).

Implication: The self-reported plant watering confirms the trend of higher water consumption for homes with irrigation systems and St. Augustine grass. The self-reported information also confirms that individuals may use similar amounts of water on plant beds and turf areas.

Self-Reported Water Use / Landscape and Irrigation Group	Turf Areas: Score for Days Between Watering	Turf Areas: Score for Duration of Watering (min.)	Plant Beds: Score for Days Between Watering	Plant Beds: Score for Duration of Watering (min.)	Number of Data Points
Xeriscape by Hand	10.8	27	6.0	14	16
Partial Xeriscape by Hand	8.6	27	8.5	13	17
Traditional by Hand	5.8	28	7.0	11	5
Xeriscape by Hose-End Sprinkler	6.6	49	6.4	28	27
Partial Xeriscape by Hose-End Sprinkler	7.9	46	8.5	21	39
Traditional by Hose-End Sprinkler	6.3	47	6.7	20	41
Xeriscape by Underground System	5.0	24	5.6	18	48
Partial Xeriscape by Underground System	5.4	17	4.2	13	12
Traditional by Underground System	5.4	26	6.3	17	40

Table A. Self-reported plant watering by xeriscape classification..

	Frequency of Watering Turf (days)	Duration of Watering Turf (minutes)	Number of Observations
St. Augustine by Hand	7.0	27	13
Other Grass by Hand	9.7	24	33
St. Augustine by Hose-End Sprinkler	6.2	42	65
Other Grass by Hose-End Sprinkler	7.6	41	42
St. Augustine by Underground System	5.1	23	75
Other Grass by Underground System	6.7	22	20

Table B. Results of the self-reported plant watering by grass type.

Model term	Parameter Estimate	Standard error	T-Statistic	Partial R-Squared
Intercept	241	76	———	———
Winter Consumption (gpd)	0.39	0.08	4.8	0.16
Days between Watering Turf	-20.4	5.6	3.6	0.12
Money (1-5 scale)	62	19	3.2	0.07
Irrigation System (0/1)	119	40	3.0	0.05
St. Augustine (0/1)	69	36	1.9	0.01
House Value ($)	0.0012	0.00048	2.5	0.02

r-squared=.42 r-squared adj.=.40

Table C. Regression results using self-reported information.

	House Value	St. Augustine	Length of Watering	Day between Watering	Money	Watering by Hand	Irrigation Systems	Winter Use	Summer
Summer Use (gpd)	.53	.17	-.15	-.40	.45	-.15	.30	.64	
Winter Use (gpd)	.34	.4	-.14	-.15	.34	.00	.14		
Underground Irrigation (0/1)	.37	.28	-.40	-.30	.33	—			
Watering by Hand (0/1)	-.12	-.31	-.15	.33	-.25				
Money (1-5 scale)	.38	.18	-.15	-.24					
Days between Watering	-.20	-.36	.15						
Length of Watering (min.)	-.15	-.03							
St. Augustine	.06								
House Value									

Table D. Correlation matrix for the self-reported information. Note: about 20 data points did not report all the information about frequency and duration of turf watering, so they were removed from the correlation analysis.

1. The number of days between watering is from question 2. Question 2 states "During the summer of 1992, approximately how often did you water your lawn? a) every day b) once every 2-4 days c) once every 5 to 7 days d) every 8 to 10 days e) less than every 10 days f) did not water last summer."

2. The length of watering is from question 5. Question 5 states "On average, for how long do you water during the summer? Lawn: a) less than 15 min. b) 15-30 min. c) 30-45 min. d) 45-60 min. e) longer than 1 hour." .

Self-reported Reason for Watering by Irrigation Method

From the questionnaire, the study team found a strong trend in the self-reported reason for watering in households with underground irrigation systems. In survey question 4, the study team asked homeowners how they determined when to water and asked them to check all that applied. About 80 percent of the households with underground irrigation systems reported watering on a set schedule or a schedule adjusted for weather. About 20 percent of the households without underground irrigation systems reported watering on a set schedule (see Table E).

Percentage with a given response	Homes with In-ground Irrigation (%)	Homes without Systems (%)
Set Schedule	14	1
Set schedule adjusted for weather	56	18
When plants look dry	24	58
When it is convenient	2	10
Voluntary city summer schedule	12	1

Table E. Self-reported reason for plant watering by irrigation method.

The study team conjectures that the reason people with underground irrigation systems tend to consume more water is that underground systems are easier to keep on a set schedule. By using a set schedule, a person will remove plant water requirements from the decision making process.

To protect one's investment in plants, the study team thinks that individuals will set the permanent schedule on their controller to at least the minimum plant water requirement for the driest part of the summer. However, if an individual does not have an underground irrigation system and waters only when their plants look dry, they will water for individual plant water requirements, not for the area water requirement.

Over-watering in homes with irrigation systems is well documented in the City of Austin irrigation audit program. The typical homeowner with an irrigation system applies about 200 gpd more water than their landscape requires. This estimate was generated by taking the average difference between the before/after schedule that the auditors calculated on 350 audits. The estimate of 200 gpd is very similar to the estimate in the regression model for the impact of an irrigation system. For homeowners without underground irrigation systems, over-watering was not as great a problem in the 50 homes audited.

Implication: The association between underground irrigation systems and set schedule watering patterns provides some understanding of the cause of irrigation systems positive association with water consumption. Educational programs like irrigation audits could be use to change customer behavior and reduce the consumption of customers with underground irrigation systems.

Appendix D: Cluster Sampling Methodology

Appendix D: Cluster Sampling

The study team selected units into the study by using a cluster sampling methodology. The sampling method examined all the households in a randomly selected cluster (a water meter reading route). The study team selected 42 clusters to examine in the study containing 7,000 homes.

Comparison between Simple Random Sample and a Cluster Sample

To enable the results to be applied to Austin as a whole (not just the areas sampled), each residential unit in the city should have the same or a known probability of selection. A simple random selection procedure, where each residential unit in the city has equal probability of selection, would meet this requirement. However, the cost of driving to homes selected by this procedure would be high. Likewise, geographic predictors are somewhat difficult to determine. Cluster sampling by selecting all units in a cluster provides each unit equal and known probabilities of selection. This probability of selection is the same as the probability of the cluster being selected (number of clusters selected into the study / number of clusters in Austin). The precision of estimates found by cluster sampling tends to be lower than the precision of estimates found by simple random samples; in other words, selecting data in clusters tends to reduce the "information" that a given data point provides. However, if the cost of data in cluster sampling is lower than simple random sampling (in this study the cost was at least a 75 percent less per data point), then a cluster sampling approach may provide more information per amount of money spent.

Combining of Clusters Selected

To reduce the number of predictor terms, the study team combined clusters to generate eight geographic locations or "pooled clusters" instead of the 42 clusters selected. The major advantage of combining clusters is that the number of terms analyzed is reduced. A reduction of terms in regression models tends to improve parameter estimates by increasing the number of data points per term. The major disadvantage of combining terms is that the data was selected using a cluster sampling approach. When cluster sampled data is analyzed by regression, model terms should be included for each cluster. However if the cluster membership is highly related to another predictor (geographic location), then the cluster membership does not need to be included in the model because both predictors describe the same information about the outcome.

Regression Results Using all Clusters as Blocking Factors

In the body of the report, the regression equations do not have cluster blocking factors because the study team chose to include the geographic location (pooled clusters) instead. When all the cluster blocking factors are included into the model, the results show the same trends towards lower water use in households with xeriscapes and higher water use in homes with underground irrigation with the values of the terms in the model being equivalent (see Table F). Also, the value for R-squared in the model is .42, about the same as .41 in the model using geographic location.

Predictor	Parameter Estimate	Standard Error	T-Statistic
Winter Water Consumption (Gal/Day)	.60	.02	30
Untended landscape (0/1)	-88	39	2.3
Grass Predictors (Xeriscape)	The grass type is an indicator variable (0/1) with St. Augustine as the comparison group.		
No Grass	-175	24	7.1
Buffalograss	-163	58	2.8
Bermuda	-83	17.5	4.8
Mixed Grass	-104	10.4	10
Irrigation System	212	11.1	19

Table F. Regression results when all clusters are included in the analysis.

The values for the 42 landscape terms ranged form -288 to 521 with standard errors from 30 to 60.

R-Squared = 0.42 F-value = 94.2
Number of data points per term in the model = 125

Appendix E: Additional Regression Models

Appendix E: Additional Regression Models

In performing multiple regression, the goal is to identify the most efficient set of predictors (the fewest number of predictors that explain the largest amount of variability about the outcome). Because more than one model can fit the data, the researcher must determine the best fitting solution. The models for the landscape and questionnaire samples in the body of the report are the models that most efficiently describe the data. However, additional information can be learned from other models. In this appendix, the study team presents the regression models in the report with variables removed and the models with additional predictors.

Landscape Data Set Regression Model with Grass Area as a Predictor

By adding the fractional amount of grass into the regression model, the study found that the amount of predicted water use increases by 49.9 gpd multiplied by the fraction of grass: 0, 1/3, 2/3, or 1. However, the standard error (27.6 gpd), low t-statistic (1.8), the probability of a sign reversal of the term in the true process (alpha = 0.07) and the low magnitude of this term suggest that it should not be included in the model (Table E1). Another reason for not including the term in the model is the low partial r-squared of 0.0002 for the number of unique observation. The true impact on water consumption of changing from full grass area to 1/3 grass area could range from -3 to 63 gpd (90 percent confidence ban on the grass fraction model term only). Even assuming the higher value in water consumption decrease, the magnitude of this term still suggests that it is not a major influence in the prediction of water use and could not be responsible for the large percentage drops that landscape experts, xeriscape advocates, have claimed for the Austin area.

The lack of a statistically significant amount of grass term, except the no grass term in the model, suggests that individuals may water plant beds for the same length of time as their turf areas. From this result, the study team concludes that promoting low water use plant beds for landscapes with primarily St. Augustine turf will not result in lower water consumption if a substantial amount of St. Augustine turf remains in the landscape. An explanation for this finding is that individuals set watering schedules for their entire landscape to at least the minimum plant water requirement of the group of plants that use the most water in their landscape (the turf area requires the most water). This conjecture is confirmed in the landscape questionnaire when individuals answered that they water their plant bed areas as often as their grass areas (see Appendix G). Also, the City of Austin Irrigation Audit Program has found that many homeowners do not zone their irrigation systems or schedules, so they will water the plant beds as much as the turf areas.

Terms in the Model	Parameter Estimate (gpd)	Standard Error	T-statistic for Ho: Parameter=0	Prob>T	Partial R^2
Winter Consumption (gpd)	0.62	0.02	31.1	0.0001	0.169
Amount of Grass (0,1/3,2/3, or 1)	49.9	28	1.8	0.071	0.0002
Untended Landscape (0/1 indicator)	-86.5	39	-2.2	0.027	0.003
Underground Irrigation (0/1 indicator)	213	11	19	0.0001	0.038
Intercept	336	17	———	———	———
Grass Type with St. Augustine as a reference group. The total partial r-squared for grass type is 0.035.					
Bermuda Grass (0/1 indicator)	-76	16	-4.6	0.0001	0.0004
Mixed Grass (0/1 indicator)	-96	10	-9.8	0.0001	0.034
No Grass (0/1 indicator)	176	24	7.3	0.0001	0.0015
Buffalograss (0/1 indicator)	-169	58	-2.9	0.0037	0.0005
Geographic location with a middle income area in North Austin as a reference group.					
Low Income Other	-137	20	-6.7	0.0001	0.009
Medium Income South	-110	12	-8.8	0.0001	0.041
High Income South	18.3	13	1.3	0.1840	0.032
Low Income North	-115	17	-6.8	0.0001	0.020
Low Income South	-160	26	-6.2	0.0001	0.031
Very High Income	325	17	18.3	0.0001	0.028
High Income North	179	14	12.2	0.0001	0.038

F-Value = 280 Degrees of Freedom = 16 , 5999 r-squared = 0.41
r-squared adj. = 0.41 Number of Data Point per Model Term = 375

Table G. The regression model with additional plant bed/grass area term.

Models to Describe Xeriscape Impact without Non-Landscape Predictors

The additional predictor are required to show the true impact of xeriscaping while statistically controlling for outside influences. Since xeriscape is associated with upper income areas, several additional predictors are required to show the water savings potential. The regression model used in the body of the report contains blocking factors for waste water, geographic location, irrigation method, and grass type. By removing these predictors, the study team can determine what the results of the study would be without collecting data on additional factors (Table H).

Without wastewater

Removing wastewater from the model decreased the r-squared value to 0.31 and did not change the magnitude of other terms in the regression model. Even though the partial r-squared is 0.17 for the waste water consumption in the regression model, the r-squared of the model is only reduced by 0.10 when it is removed from the model. The information explained by indoor use is partially explained by other predictors in the regression model.

Without house value determined by geographic location

Using the model of best fit without geographic blocking produces a different set of public policy conclusions. First, Buffalograss does not appear to reduce water use by a large amount and a statistically significant difference could not be found (unlike the model of best fit where Buffalograss reduces predicted consumption by 174 gpd). Also, the impact of an underground irrigation on predicted water use is greatly increased by removing geographic location (213 to 336 gpd). The association between irrigation method and geographic location (house value) should be noted for all future studies on water consumption.

Grass type only

Removing these predictors from the model reduces the r-squared statistic to less than 0.1 (an unacceptable level for research). The value of the r-squared and the xeriscape predictors is similar to what was found in the first xeriscape study that did not contain blocking factors other than lot size. This finding confirms that in the absence of other predictors, xeriscape characteristics may describe very little information about water use.

Xeriscape (Buffalograss and no grass) only

The primary xeriscape grasses targeted for promotion by water conservation experts are Buffalograss and no grass. No grass is associated with a 13 percent reduction in water use. The results however were not statistically significant for Buffalograss, showing no difference in water consumption. The conclusion without any additional predictors is that xeriscape does not save water. However, this conclusion without the controlling factors of irrigation method and house value is inaccurate due to xeriscape being concentrated in high income areas. Exploring water use from observational/correlational data without an adequate list of predictors is equivalent to comparing apples to oranges.

Predictors	Original Data Set Parameter Estimate	Without Indoor Use	Without Geographic Location	All Grass Types	Xeriscape Grasses
Grass Predictors (Xeriscape)	The grass type is an indication 0/1 variable with St. Augustine as the comparison group. The results of the study (the potential water savings of Xeriscape promotion) are based only on these terms.				
No Grass in Landscape	-173	-147	-162	-139	-72
Buffalograss	-174	-198	-92	-178	-111
Bermuda Grass	-80.7	-88	-68	-116	——
Mixed Grass	-97.6	-99	-113	-202	——
Blocking Factors and Intercept Term					
Intercept Term	359	477	327	——	——
Winter Consumption (gal/day)	.612	——	.65	——	——
Underground Irrigation (0/1 indicator)	214	256	336	——	——
Location (Demographic)					
Untended Landscape (0/1 indicator)	-84.9	-101	——	——	——
Very High Income Areas	324	378	——	——	——
High Income Areas in North Austin	176	161	——	——	——
High Income Areas in South Austin	17.2	4	——	——	——
Middle income areas in South Austin	-110	-109	——	——	——
Low Income Areas in North Austin	-116	-117	——	——	——
Low Income Area in South Austin	-161	-166	——	——	——
Other lower Income areas	-141	-144	——	——	——
Model Statistics	The r-squared and T-statistic of Xeriscape promotion items of the 3 models provides insight into what public policy conclusions could be developed from the different model.				
Total R^2	0.41	0.31	0.32	0.05	0.001
T-Statistic for Buffalograss	3.0	3.2	1.47	2.4	1.47
T-Statistic for No Grass	7.1	5.5	6.3	4.5	2.35

Table H. The regression results with terms removed for the landscape sample.

Landscape Data Set Analysis Using a Least Squared Means Procedure

A least squared means procedure calculates a predicted value, "mean estimate," for a single classification (grass type) while controlling for all other differences (geographic location, cluster membership, and irrigation method) using least squares regression. The least squared mean shows the predicted value at the most central tendency of the data (SAS, 1993). This procedure is an informal data analysis method based on data exploration. However, as a data analysis method, it provides some additional insight into the central tendency in a data set. The estimates are similar to the results found with regression for the grass type term. However, the least squared means provides a single numerical "average" of water consumption for each grass type if all landscapes have similar geographic locations, indoor use, and irrigation methods (Table I).

The least squared means results show that Buffalograss and no grass landscapes would "average" 379 gpd compared to 554 gpd for St. Augustine. From this difference, the study team estimates a 31 percent reduction (175 gpd) in average estimated water consumption associated with xeriscape at the most central point in our data set. Likewise, the results show an estimated 473 gpd consumption for Bermuda grass and 457 gpd consumption for mixed grass. This corresponds to a 15 percent difference for Bermuda grass and a 18 percent difference for mixed grass.

Table I. Estimated least squared means for grass type in the landscape data set controlling for irrigation method and geographic location.

Grass Type	Summer Water Use Least Squared Mean Est. (gpd)
St. Augustine	554
Buffalograss	381
No Grass	379
Bermuda	473
Mixed Grass	457

Search for Meaningful Interaction Effects

A search for meaningful interaction terms showed that an interaction term was not justified in the regression model. This finding suggests that the difference in predicted consumption between a xeriscapes and a traditional landscapes is constant over all house values and irrigation types. As a result, the predicted percentage savings from xeriscape is greater in medium or lower income areas without underground irrigation systems. The percentage impact of xeriscaping seems to decrease as income level increases.

Interaction between low water use grasses (mixed, Bermuda, St. Augustine, or no grass) and underground irrigation

The study team used a 0/1 indicator variable to determine whether the presence of an irrigation system and low-water use grasses together changed the predicted water consumption by a statistical significant difference than the presence of both factors considered separately. The value of the interaction term in the model was 32 with a standard error of 22 (t-statistic 1.4). A positive interaction term implies that the impact of xeriscaping decreases when an irrigation system is in the landscape. This result is expected from the mean values without controlling for house value (Table 5). Statistical controlling for house value decreases the influence of the apparent interaction shown in the mean values.

Interaction between low water use grass and house value

As a group, the interaction effects between the eight categories for geographic location (house value) and grass type are not statistically significant. The f-statistic* for the addition of the 24 terms shows that there is a 10 percent chance that the information explained by the terms in the least squares fit could be explained by a predictor that had nothing to do with the outcome. Also, a clear trend in the sign of the terms was not found. A similar model with an interaction term with house value estimated by geographic location (1,0,-1 scale) showed that an interaction term was not statistically significant.

Interaction between all factors

Including blocking factors for a three-way interaction between house value (geographic location coded as 1, 0, -1), irrigation method, and grass type did not add any additional information to the model. The value of R-squared adjusted for the number of terms in the model decreased with the additional terms. Most of the additional terms were not statistically significant and the f-statistic for the group of terms was not statistical significant.

* An f-statistic shows the probability that the information explained by a set term in the model could be explained by normal variability or error in the data. The F-statistic determines if a group of terms should be included in the model by giving the chance that the terms explain nothing.

Additional Models to Describe the Questionnaire Data Base

Since the questionnaire database contains several predictors for the same information, multiple models will fit the data set. However, the estimated influence of grass type on water consumption does not change in the numerous models with an acceptable list of predictors.

Models using true house value instead of house value determined by geographic location

The model using house value determined by tax records instead of geographic location shows that the predictors have a similar relationship to water use. The value of the partial r-squared in the best fitted model is 0.03 for both predictors. Also, the first order correlation between the predictor is 0.65 with correlations to other predictors being similar.

Models using time spent landscaping instead of money

The predictor of time spent landscaping is statistically significant (t-statistic=1.9) only when the term for money spent landscaping is not included in the model. With only one of the terms in the model, the magnitude of the time spent landscaping term is 1/3 of the money spent term and the partial r-squared is smaller. The study team conjectures that the relationship between time spent landscaping and water use is weak and positive, but this relationship can not be detected in the 260 point data set due to the correlation between money and time spent landscaping.

Models including self-reported irrigation method (hand, hose-end, underground, and drip)

Since the data set only contained six respondents who used drip and all drip respondents also used an underground system, the study team could not detect a difference between underground system with and without drip. A larger sample size could determine if drip irrigation reduced consumption.

The water-by-hand term predicted 100 gpd less consumption than hose-end watering with a standard error of 85 gpd (Table J). The partial r-squared of the hose-end term suggest that this term absorbs a substantial amount of information as a blocking factor. The negative sign of the watering by hand term and the positive sign of the underground irrigation term suggest that individuals water more when it is easy to do. However, the model term for watering by hand is not statistically significant (t-statistic = -1.1) with a 23 percent chance of a sign reversal in the true process, so the term was not reported as the model of best fit.

Model Term	Parameter Estimate (gpd)	Standard Error	T-statistic	Standardized Estimate	Semi-Partial R-Squared
St. Augustine Grass (1/0)	168	62	2.7	0.12	0.015
Winter Consumption	0.47	0.05	9.0	0.43	0.31
Watering by Hand Instead of Underground or Hose-End	-100	84	-1.1	-0.05	0.04
Underground Irrigation	144	70	2.1	0.11	0.06
Money Spent	75	34	2.2	0.11	0.026
Pool (0/1)	177	88	2.0	0.09	0.013
Lower Income Area (1/0)	-181	68	-2.6	-0.13	0.03
Higher Income Area (1/0)	309	75	4.1	0.20	0.03
Intercept	302	97	———	———	———

f-statistic = 36
R-squared= 0.531 R-squared adjusted= 0.516

Table J. Model of best fix using self-reported information about irrigation method including watering by hand.

Regression Results with Terms Removed for the Questionnaire Data Set

By removing terms from the model, the study team examined models that could be produced by including a smaller list of predictors. In the questionnaire data set, reduced models are an important analysis in determining what terms are most important.

Without house value determined by geographic location

The removal of the house value from the equation increased the magnitude of the irrigation method and money spent landscaping terms in the regression model. However, the r-squared value for the model does not dramatically change. The high correlation between irrigation method, money spent landscaping, and house value made determining what unique factors control water use difficult and somewhat subjective (Table K).

Without winter consumption

The removal of winter consumption from the regression model decreases the r-squared from .54 to .37. This drop shows that winter consumption (indoor use) explained a large portion of the variability in the data set. Also, the removal of winter consumption increased the value of the terms for irrigation method and money spent landscaping.

With irrigation method, money spent landscaping, and St. Augustine grass

The model with terms for money spent landscaping, irrigation method, and St. Augustine grass shows that these predictors describe a substantial amount of information about the data set (r-squared = .31). This finding suggest that money spent landscaping is a good predictor of water use. Because of the amount of information described by these terms, the three predictors of *money spent landscaping (landscape effort), grass type, and irrigation method* should always be considered on all future studies of residential water use.

	Original Data Set Term Estimate (gpd)	Without Winter Consumption	Without House Value	With Irrigation Method, Grass Type and Money
Presence of St. Augustine in Landscape (0/1)	189	209	182	196
Underground Irrigation (0/1 indicator)	127	244	268	384
Money Spent Landscaping (1-5 Scale)	82	189	125	196
Winter Consumption (Gal/day)	.47	———	.42	———
High Income Area (1/0 indicator)	308	261	———	———
Low Income Area (0/1 indicator)	-194	-115	———	———
Pool (0/1 Indicator)	175	229	225	———
Intercept Term in the Model	267	360	166	300
R-Squared of the Model	0.52	0.37	0.45	0.31

Table K. Regression equations for the questionnaire sample with several terms removed.

Appendix F: Chemical Use

Appendix F: Chemical Use

From the start of the investigation of outdoor chemical use, the study team hypothesized that individuals with a xeriscape landscape would use lower amounts of outdoor chemicals. This initial hypothesis was generated by reading xeriscape promotion material and discussions within ECSD Staff. To confirm this initial hypothesis, the study team asked about chemical use patterns in the mailed questionnaire. The questionnaire inquired about the number of applications per year of pesticides, weed killers, and fertilizer. Each question had response levels of 0, 1-2, 3-4 or more than 4 times per year. Also, the questionnaire asked about the type of chemicals used.

The analysis of the questionnaire revealed:

- Xeriscaping, partial xeriscaping, and traditional landscaping used outdoor chemicals with the same frequency (Table L and M).
- Landscape classification does not have a strong correlation with frequency of outdoor chemical use.
- Use of a given outdoor chemical type (weed killer, fertilizer, or pest control) is a good predictor of use of other outdoor chemicals types. These correlations ranged from 0.36 to 0.45.
- Xeriscapes tend to use safer products than traditional landscapes, but the magnitude of difference is small. Also, the small number of respondents who reported using a given product make this information difficult to examine (Table L).
- St. Augustine landscapes (60%) are more likely to use lawn fertilizers such as Scotts, Fertilome, or Hi-Yield than other landscapes (40%).
- Individuals who participated in the "Xeriscape-It" rebate program reported using less fertilizer on their Buffalograss than their previous grass (see Appendix H).

Promoting xeriscape in environmentally sensitive areas as a method of lowering chemical use may not result in large improvements in water quality according to the questionnaire results. However, the self selection questionnaire return procedure, lack of questions about amount, and lack of questions about other predictors that could have a relationship to chemical use makes these results highly speculative. Also, the runoff from a xeriscape has been shown to be less dangerous than the run-off from a traditional landscape for similar care levels in outdoor test sites (Hipp, 1993).

Product Name/ Number Who Reported Using a Given Product	Xeriscapes (85 total respondents)	Partial Xeriscape (81 total respondents)	Traditional (102 total respondents)	St. Augustine (168 total respondents)	Other Grass (100 total respondents)
Pest Controls					
Latticed	0.00	0.00	0.00	0.00	0.00
Bt	0.02	0.01	0.00	0.02	0.00
Exhibit	0.01	0.00	0.00	0.00	0.01
Hinder	0.00	0.00	0.02	0.00	0.02
Insect	0.05	0.07	0.01	0.03	0.06
Malathion	0.19	0.07	0.17	0.18	0.08
Precor	0.00	0.00	0.01	0.01	0.00
Pyrethrin	0.07	0.05	0.05	0.07	0.03
Safer soap	0.12	0.12	0.07	0.11	0.09
Thuricide	0.09	0.04	0.00	0.05	0.03
Diazinon	0.35	0.28	0.40	0.40	0.26
Dursban	0.12	0.12	0.25	0.21	0.10
Sevin	0.19	0.23	0.27	0.27	0.18
Diatomaceous Earth	0.09	0.12	0.07	0.08	0.12
Weed Killers					
Balan	0.01	0.00	0.03	0.02	0.01
Dacthal	0.00	0.00	0.00	0.00	0.00
Eptam	0.00	0.01	0.00	0.01	0.00
MSMA	0.00	0.01	0.00	0.01	0.00
Np Huric	0.00	0.00	0.01	0.01	0.00
Round-Up	0.24	0.17	0.21	0.19	0.23
Weed Be Gone	0.24	0.17	0.21	0.14	0.11
Weed & Feed	0.11	0.17	0.20	0.17	0.15
Fertilizers					
Austinite	0.01	0.00	0.02	0.02	0.00
Blood Meal	0.15	0.06	0.12	0.15	0.05
Compost	0.29	0.19	0.19	0.21	0.23
Dillo Dirt	0.07	0.04	0.08	0.07	0.05
Miracid	0.04	0.02	0.08	0.06	0.03
Milorganite	0.01	0.02	0.04	0.03	0.02
Miracle Grow	0.27	0.31	0.31	0.30	0.29
Osmocote	0.07	0.02	0.05	0.07	0.02
Lawn Fertilizers	0.48	0.48	0.65	0.60	0.45
Super Bloom	0.13	0.10	0.11	0.12	0.10
Sustain	0.05	0.01	0.01	0.02	0.02

Table L. Fraction of individuals who responded using a given chemical product by grass type and xeriscape classification.

Appendix F.3- Chemical Use

Correlation Matrix	Chemical Pesticides	Biological Pest Control	Chemical weed killers	Chemical Fertilizers	Organic Fertilizers	Time Spent Landscaping	Money Spent Landscaping	House Value	Partial Xeriscape	Xeriscape
Xeriscape	.03	.15	-.05	-.04	.08	.00	.18	.39	——	
Partial Xeriscape	-.08	.07	.07	-.13	.02	-.06	-.20	-.18		
House Value	.20	.09	.10	.16	.08	.13	.39			
Money Spent Landscaping	.28	.19	.18	.28	.22	.33				
Time Spent Landscaping	.22	.08	.16	.22	.18					
Organic Fertilizers	.10	.51	.14	.00						
Chemical Fertilizers	.45	.07	.36							
Chemical Weed Killers	.43	.12								
Biological Pest Control	.29									
Chemical Pesticides										

Table M. First order correlations for chemical use.

Appendix G: Summer 1993 Water Consumption

Appendix G: Summer 1993 Water Consumption

In the summer of 1993, the City of Austin had no rainfall for two months. Due to the lack of rain, record levels of water consumption were set. By examining the landscape sample, xeriscaping, house value (neighborhood influence), and irrigation methods impact on consumption in a very dry year was determined. Water treatment plant sizes and other water distribution capital cost are determined by the demand for water at the maximum peak day. Due to the long dry conditions, the summer of 1993 was close to the maximum peak day water use.

To develop inferences about the change in the predictor-outcome relationship caused by the dry conditions of 1993, the study team performed the same analysis as presented in the report on the landscape sample (see Table N and Table O). These differences in the regression equations were found:

- Upper income areas had larger increase in consumption between 1992 and 1993 than middle income areas (304 gpd compared to 208 gpd for a home without an irrigation system with St. Augustine). Similarly, lower income areas did not experience a large change in water consumption (13 gpd for a home without an irrigation system with St. Augustine). This result suggests that upper income area have a large influence on maximum peak day and system size requirements.

- The predicted increase in residential consumption associated with irrigation systems increased from 214 gpd to 321 gpd (see Table O). This increase associated with irrigation systems combined with the increase in upper income areas strongly suggests that middle to upper income and upper income customers greatly influence peak demand.

- The predicted reduction in consumption from no grass increased from -174 gpd to -250 gpd. This result suggests that the water use patterns of home owners with no grass xeriscapes do not change as much as traditional landscapes in an extended dry period.

- The predicted reduction in residential consumption associated with Buffalograss decreased from -174 gpd to -89 gpd. This decrease could be due to the limited number of Buffalograss landscapes (random error) or the concentration in upper income areas. From the 1993 and 1992 parameter estimates, Buffalograss homeowners appear to have similar demand patterns to Bermuda grass and mixed grass. Note: the Buffalograss term was not statistically significant (alpha = 0.05) in the 1993 data, but it was significant in the 1992 data (95% confidence level).

- Bermuda and mixed grass landscapes predicted about 150 gpd less consumption per day than St. Augustine landscapes in the summer of 1993. In the summer of 1992, the difference was about 90 gpd.

Irrigation Method	Grass Type	Mean Summer Consumption 1993 (gpd)	Mean Summer Consumption 1992 (gpd)	Difference	Number of Site
No Irrigation Systems	St. Augustine	827	480	347	2573
	All grass Except St. Augustine	590	352	238	1996
	Bermuda	588	359	229	342
	Mixed Grass	592	350	242	1503
	Buffalograss	783	407	376	31
	No grass	529	345	184	126
Irrigation Systems	St. Augustine	1365	860	505	1131
	All grass Except St. Augustine	1292	809	483	261
	Bermuda	1444	926	518	92
	Mixed Grass	1271	793	478	160
	Buffalograss	1851	471	1380	5
	No grass	1064	696	368	59

Table N. Mean water consumption by irrigation method and grass type for summer 1993.

Predictors	Parameter Estimates 1993	Parameter Estimate 1992	Standard Error 1993/1992	T-Statistic for True Parameter Equals 0
Intercept Term	529	359 gpd	17 / 11	30 / 31.8
Winter Consumption (gpd)	1.09	.61	.03 / .02	34 / 31.9
Irrigation System (0/1 indicator)	321	214 gpd	17 / 11	19 / 19.8
Grass Predictors (Xeriscape)	The grass type is an indicator 0/1 variable with St. Augustine as the comparison group. The partial r-squared for the grass predictors is .035.			
No Grass in Landscape	-250	-173 gpd	38 / 24.3	-6.6 / -7.2
Buffalograss	-89	-174 gpd	89 / 58.4	-1.0 / -3.0
Bermuda Grass	-144	-81 gpd	25 / 16.3	-5.7 / -4.9
Mixed Grass	-149	-98 gpd	15 / 9.8	-9.8 / -10.0
Geographic Location (House Value)	The location of the house is an indicator variable with middle income area in far North Austin as the reference group. The r-squared partial for location is .165.			
Very High Income Areas in North Austin	458	324 gpd	27 / 17.8	16 / 18.2
High Income Areas in North Austin	131	176 gpd	22 / 14.5	5.8 / 12.1
High Income Areas in South Austin	56	17.2 gpd	21 / 13.8	2.6 / 1.3
Middle Income Areas in South Austin	-120	-110 gpd	19 / 12.5	-6.2 / -8.9
Low Income Areas in North Austin	-110	-116 gpd	26 / 16.9	-4.1 / -6.9
Low Income Area in South Austin	-318	-161 gpd	40 / 25.7	-7.9 / -6.3
Other Lower Income Areas	-279	-141 gpd	32 / 20.5	-8.7 / -6.9

Table O. Comparison of the 1992 and 1993 regression parameter estimates for water use using landscape predictors.

1993 r-squared=.39
1992 r-squared=.42

Appendix H: Customer Feedback on Buffalograss

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The Water Conservation Division mailed a questionnaire to all homes that have received a rebate for Buffalograss As part of the ongoing Outcome Evaluation Research Program. The rebate is 8¢ per square foot of installed Buffalograss up to a maximum $240 rebate. This questionnaire collected customer feedback on water savings from Buffalograss, reason for installation, problems with weeds, problems with infiltration of unwanted grasses, reaction to appearance, and chemical use. The questionnaire had a high response rate of 73 percent with 74 surveys returned. This customer feedback is an important research tool for learning about the free ridership, water savings, chemical use and a multiplier effect from social diffusion. These factors are the critical unknowns in the cost-effectiveness analysis (see page 28).

Water Savings and Chemical Use

On question 2 of the survey (see Figure A), 89 percent of question respondents reported watering Buffalograss less than their old grass. The large percentage of homeowners who perceive that they are using less water suggest that the rebate program is producing positive customer expectations (see Social-Behavioral model on page 30). The expectations and perceived reductions in consumption are critical to the objective long term reduction in consumption from conservation programs (Aronson and Gonzalez 1990; Geller,1983). Likewise, a majority of respondents reported using less fertilizer (61 %).

The major self-reported reasons for participation in the program on question 8 were water conservation (72 %), reduce water bill (71 %), environmental concerns (29 %), and low maintenance requirements (78 %). These reasons for participation suggest that individuals who install buffalograss have the expectation of lowering water consumption.

Social Diffusion

On question 7, 84 percent reported that they would definitely recommend planting Buffalograss to a friend (16 % maybe and 0 % would not recommend it). This high fraction of individuals who would recommend the product to a friend suggest that interpersonal communication within neighborhoods (see page 30) and social networks will help promote Buffalograss and produce a positive multiplier effect (see page 28) in the community. Even though there will be a time lag, customer receptivity to the program and participation rates in the program should increase as individuals who participate in the program tell their friends and neighbors about the advantages of Buffalograss lawns.

Another indicator of a positive social diffusion of the product is the positive reaction to its appearance: 74 percent rated it excellent; 23 percent rated it fair; and 3 percent rated it poor. A positive reaction to its appearance may encourage others who view the lawn to plant Buffalograss.

Free Ridership

On question 6, 68 percent reported that they would have planted Buffalograss without the rebate program. As the program moves from a trial phase to a full scale phase, the amount of free ridership should decrease as more homeowner participate in the program. Also, many of the early participants learned about Buffalograss through Water Conservation public information even if the rebate did not influence their choice (For more information on the public information program, see Chaumont and Gregg, 1993).

1. How would you rate the appearance of your buffalo grass ? ☐ Excellent ☐ Fair ☐ Poor
2. How often do you water your buffalo grass, compared to your old grass? ☐ Less ☐ More ☐ The Same
3. How often do you fertilize your buffalo grass, compared to your old grass? ☐ Less ☐ More ☐ The Same
4. If you do not live in a new home, what type of grass did you have before planting buffalo grass; or if you live in a new home, what type grass did you have at your previous home before planting buffalo grass?

   ☐ St. Augustine ☐ Bermuda ☐ Other Grass (List) ☐ I live in a new home and I never had a home before
5. Compared to your old grass, does your buffalo grass have problems with:
   - (a) Weeds ☐ Less ☐ More ☐ The Same ☐ Don't Know
   - (b) Infiltration of Other Grasses ☐ Less ☐ More ☐ The Same ☐ Don't Know
   - (c) Pests ☐ Less ☐ More ☐ The Same ☐ Don't Know
6. Would you have planted buffalo grass without the rebate program? ☐ Yes ☐ No
7. Would you recommend planting buffalo grass to a friend? ☐ Definitely Yes ☐ Maybe ☐ Definitely No
8. What were your primary reasons for planting buffalo grass?

   ☐ Water Conservation ☐ Community Standards ☐ Environmental Concerns
   ☐ Reduce Water Bill ☐ Rebate Program ☐ Low Maintenance Requirements

   Please list any other reasons for planting buffalo grass: ______________________
9. How would you rate the customer service you received from the Water Conservation Program?

   ☐ Excellent ☐ Fair ☐ Poor If "poor," what problems did you experience? ______________

Figure A. Questionnaire for customer feedback about the rebate program.

Appendix I: Research Team

Appendix I: Research Team Members

Tony Gregg, P.E.

Tony Gregg holds a B.S. in Civil Engineering from Bucknell University. His expertise includes all areas of integrated resource planning and water conservation program development, evaluation, and research. Since 1990, he has been the Water Conservation Division Manager at the City of Austin. He is an active member of American Water Works Association (AWWA) and is currently the chair of the Texas Water Conservation and Reuse Division and co-chair of the National AWWA Planning and Evaluation Standards subcommittee.

Charles W. Grigsby, Ph.D.

Charles Grigsby holds a doctorate in applied social psychology from the University of Texas at Austin. His expertise includes applied social-behavioral research, multivariate statistical analysis, and program evaluation. In addition to serving on a variety of special research projects at the City of Austin, and teaching social psychology at Austin Community College, Dr. Grigsby is employed as a Research Specialist in the City's Human Resources Department.

James Curry

James Curry holds a B.S. in Mechanical Engineering from the University of Texas at Austin and is currently working on a M.S. in Operations Research from the University of Texas at Austin. His research interests are multivariate statistics, simulation, and analysis of the effectiveness of water/energy conservation programs. He is currently employed by the City of Austin as a Research Associate.

Deborah Phillips

Deborah Phillips holds a B.S. in Landscape Architecture from Texas A&M. Her expertise includes landscape construction, xeriscaping, and efficient irrigation. She was employed by the City of Austin as a Landscape Architect and was responsible for the *"Xeriscape-It"* Rebate Program, Irrigation Rebate Program, and Irrigation Audit Program.

Patrick Basinki

Patrick Basinki holds a B.A. from the University of Texas at Austin and a Master of Public Affairs from the University of Texas. His research interests include environmental policy, water resource planning, and water quality management.

Barry Landry

Barry Landry holds a B.S. in Landscape Architecture from Louisiana State University. His primary interest is landscape design.

Nancy Charbeneau

Nancy Charbeneau holds a Masters in Landscape Architecture from Texas A&M University with undergraduate degrees in Biology and Education. Her expertise includes conservation research and education, landscape planning and design, and computerized planning systems.

David McKay, Ph.D.

David McKay is Coordinator of Organizational Research for the City of Austin.